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Regional Air Pollution Study Point Source Emission Inventory

Rockwell International, Creve Coeur, Mo Air Monitoring Center

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Environmental Sciences Research Lab, Research Triangle Park, N C

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March 1977

REGIONAL AIR POLLUTION STUDY
Point Source Emission Inventory

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Contract 68-02-1081
Task Order 56

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ABSTRACT

Emissions data from stationary point sources in the St. Louis Interstate Air Quality Control Region (AQCR) have been gathered during the calendar year of 1975. Data for "criteria" pollutants will be available on an hourly basis. Emissions from large sources are based on hourly, measured values of pertinent operating parameters. Those from smaller sources, between 10 and 1000 tons per year are based on annual data modified by a detailed operating pattern.

An emission factor verification program has been initiated. It is carried out by source testing of typical sources using standard EPA methods. Results obtained so far indicate good agreement for SO_2 values. The data obtained for NO_x and particulates originating from combustion sources tend to indicate that the existing factors are too high by variable but substantial amounts.

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1.0 SUMMARY

Emissions data from stationary point sources in the St. Louis Interstate AQCR have been gathered during the calendar year of 1975. Data for "criteria" pollutants - SO_2, NO_x, Particulates, CO and Hydrocarbons - will be available on an hourly basis. Emissions from large sources are based on hourly, measured values of pertinent operating parameters. Those from smaller sources, between 10 and 1000 tons per year of SO_2, for example, are based on annual data modified by a detailed operating pattern.

An emission factor verification program has been initiated. It is carried out by source testing of typical sources using standard EPA methods. Results obtained so far indicate good agreement for SO_2 values. The data obtained for NO_x and particulates originating from combustion sources tend to indicate that the existing factors are too high by variable but substantial amounts.

2.0 INTRODUCTION

This is the third of a series of reports describing the operation of the Regional Air Pollution Study (RAPS) Point Source Emission Inventory. The two prior reports dealt with the methodology (EPA 450/3-74-054) and the first six months of operation of the inventory (SC553.TO16FR). This report describes the data acquisition for May through December 1975, as well as the emission factor verification program carried out by stack sampling during the same period.

3.5 EMISSION DATA ACQUISITION

During the period of 1 May to 31 December 1975, the collection of hourly, measured data from all major sources of SO_2 was continued. The methodology used is described in detail in "Point Source Emission Inventory - Final Report, Task Order 16, Phase II" EPA Contract No. 68-02-1081, dated May 1975.

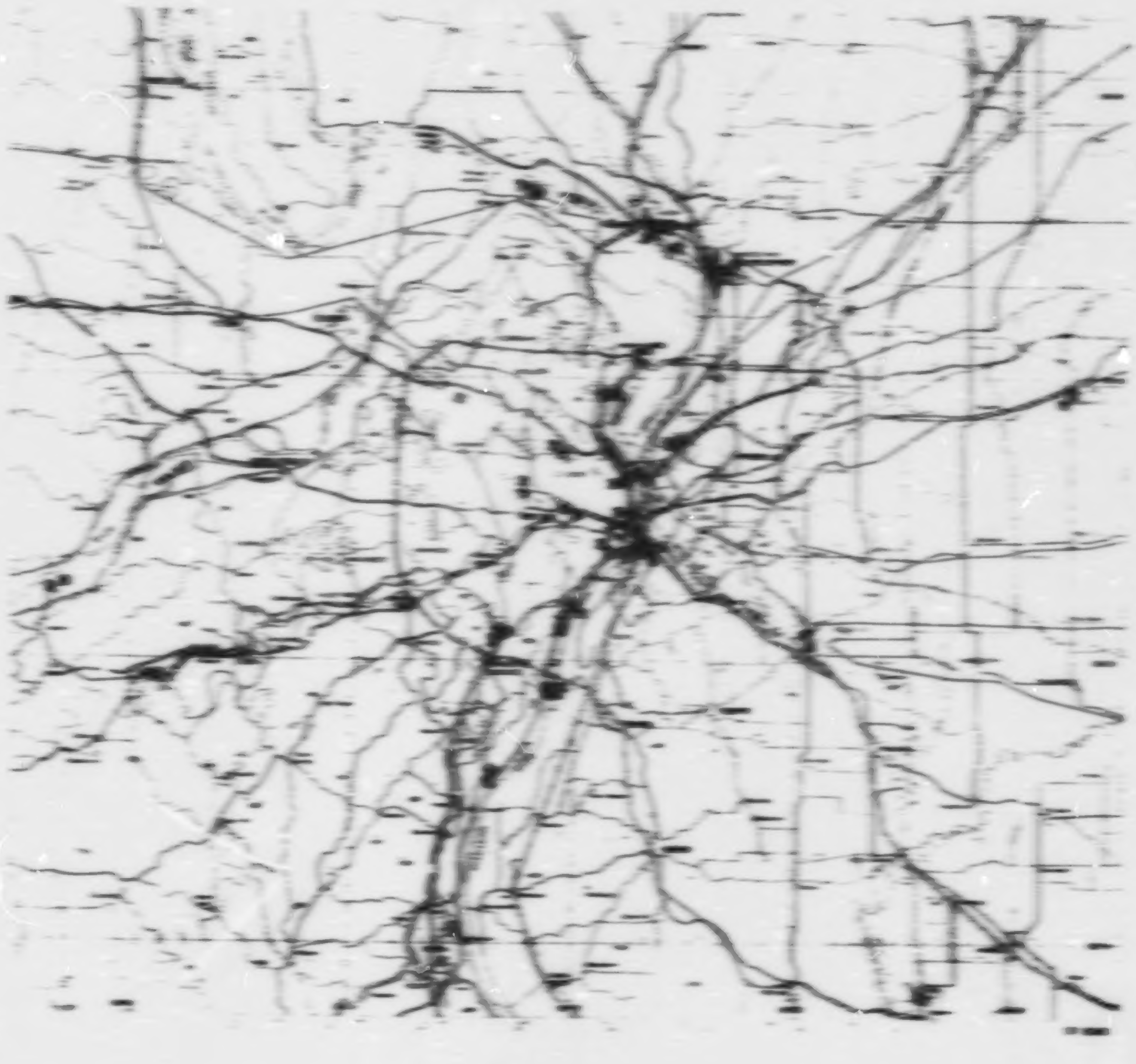
Hourly process or consumption data covering 145 points were recorded and coded on punched cards as described in the same report. The cards were verified and processed through an editing routine (also described in the named report). The information was then transferred to the Univac 1110 computer at the National Environmental Research Center at Research Triangle Park, NC. Major point sources in the St. Louis AQCR are shown in Figure 1.

The emissions from 60 smaller sources were obtained and recorded as annual data, together with the operating patterns. The pattern is capable of indicating the actual operating hours, operating days (in Julian form) and weekly patterns by days. For example, the entry

D:2-48, 50-184, 186-244, 246-365, W:1-5, H:8-17

denotes the operation of a plant which normally operates Monday through Friday (W:1-5), from 8 AM to 5 PM (H:8-17), but is closed down for New Year's (D:1), Washington's Birthday (D:49), Independence Day (D:185), and Labor Day (D:245). If an hourly output for a specific hour and day is requested, the computur will first make sure the plant was operating that day, then divide the annual number by the actual number of hours of operation for a 5 day week, 9 hours a day operation, less the number of days when the plant was shut down.

A 3 month long strike at Union Electric Company delayed the acquisition of data from all U.E. plants; however, since the resumption of normal conditions, the delayed data are forthcoming.



RAPS
Major Point Source
Emissions

FIGURE 1

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/4-77-014	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE REGIONAL AIR POLLUTION STUDY Point Source Emission Inventory		5. REPORT DATE March 1977
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Fred E. Littman, Robert W. Griscom, and Otto Klein		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Rockwell International Air Monitoring Center 11640 Administration Drive Creve Coeur, MO 63141		10. PROGRAM ELEMENT NO. 1AA603
		11. CONTRACT/GRANT NO. 68-02-1081 Task Order 55
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Sciences Research Laboratory - RTP,NC Office of Research and Development U.S. Environmental Protection Agency Research Triangle Park, N.C. 27711		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE EPA/600/09
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

Emission data from stationary point sources in the St. Louis Interstate Air Quality Control Region were gathered during 1975. Data for "criteria" polutants were obtained on an hourly basis. Emissions from large sources were based on hourly, measured values of pertinent operating parameters. Those from smaller sources, between 10 and 1000 tons per year, were based on annual data modified by a detailed operating pattern. Examples of the data are presented in the report. The full set of data are available from the RAPS Data Bank.

An emission factor verification program was initiated by testing typical sources using standard EPA methods. Results indicate good agreement for SO_2 values. Data for NO_x and particulates originating from combustion sources indicate that the existing factors are too high by variable but substancial amounts.

17. KEY WORDS AND DOCUMENT ANALYSIS

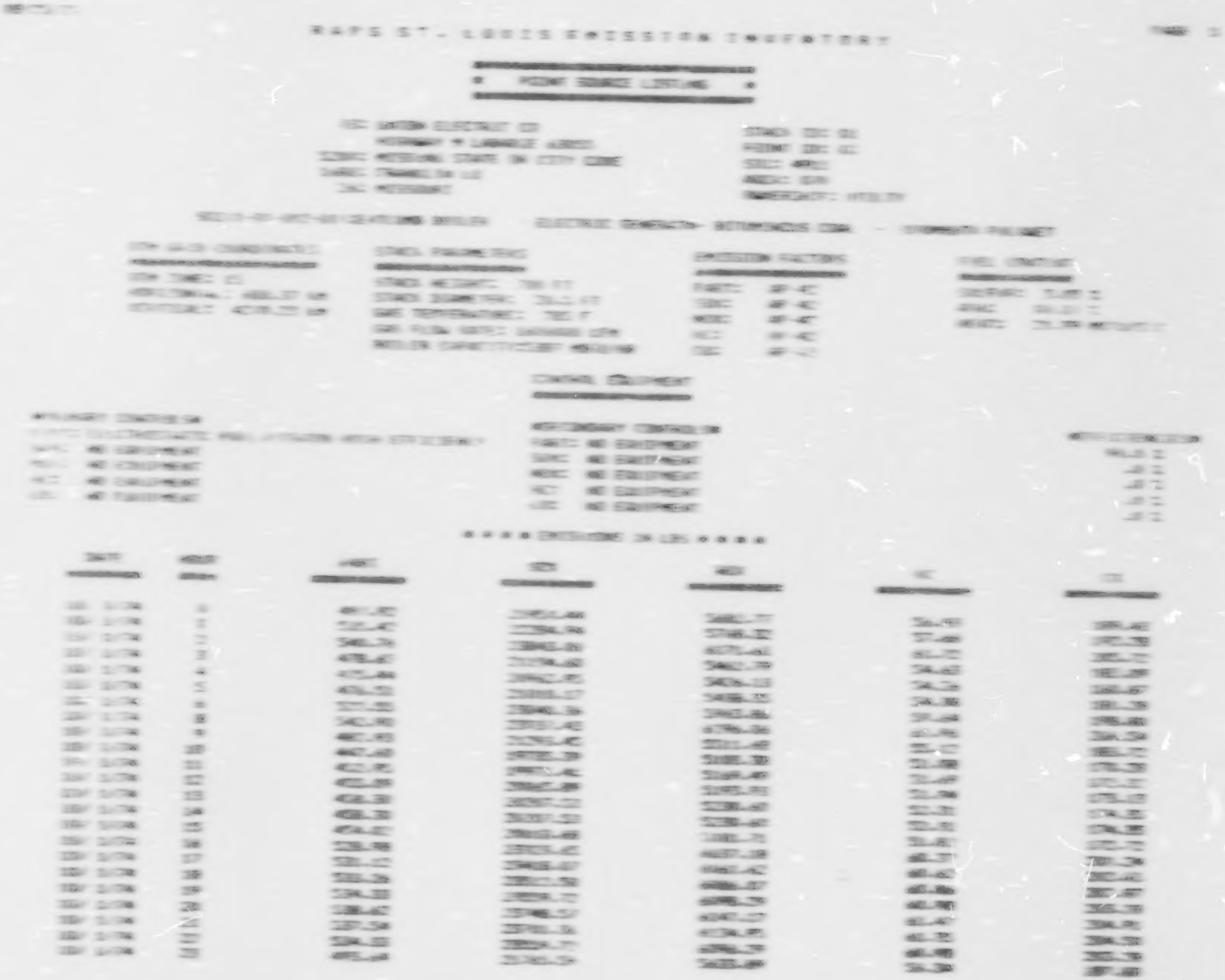
a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Air pollution *Emission *Data *Collection	St. Louis, MO Stationary point sources	13B

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 354
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE PC A16 - A01

Arrangements are being made with all companies furnishing data to continue the data collection through 1976. It appears that most, if not all, companies will again cooperate in this effort.

Once the necessary output programs become fully operational, it will be possible to obtain emissions for criteria pollutants emanating from stationary sources for any one-hour period in the St. Louis AQCR for the calendar year of 1975. The information for hydrocarbon emissions will be refined and supplemented under a separate task order next year.

A typical printout, showing hourly data for Particulates, SO_2, NO_x, Hydrocarbons (HC) and CO, is shown in Figure 2. The printout gives name and address of the source, its classification, location in UTM coordinates, stack parameters, fuel analysis and method of calculation, in addition to the emission values.



RAPS ST. LOUIS EMISSION INVENTORY

POINT SOURCE LISTING

FIGURE 2 - POINT SOURCE LISTING

4.0 EMISSION FACTOR VERIFICATION STUDIES

4.1 INTRODUCTION

Emission estimates are based on consumption or production figures from which emissions are calculated using an emission factor. Emission factors are averaged numbers relating emissions to consumption or process data. In some cases, the relationship is direct and relatively uncomplicated. For example, for every ton of bituminous coal burned, a total of 38S pounds of sulfur dioxide is produced, where S indicates the sulfur content of the fuel, on a weight percent basis. Thus, if a plant burns 100 tons of 3% sulfur coal per hour it emits

$$100 \times 38 \times 3 = 11,400$$

11,400 lbs of SO_2 per hour. Since in this particular case the sulfur is contained in the fuel and is converted virtually completely to SO_2, the numbers resulting from the use of the emission factor are quite accurate and reliable.

If, on the other hand, we wish to determine the amount of oxides of nitrogen produced by the same operation, a somewhat different situation ensues. The emission factor for a boiler burning bituminous coal, as given in the EPA publication AP-42 "Compilation of Air Pollution Emission Factors", varies with both boiler type and size, from 6 to 55 lbs. of NO_x per ton of coal. This is because the factors affecting NO_x production include flame and furnace temperature, residence time of the combustion gases, rate of cooling, amount of excess air, as well as the amount of nitrogenous compounds in the fuel. Thus, the emission factor of 18, which is applicable to a pulverized coal boiler of this size, is an averaged value. Actual values may depart significantly from the numbers obtained by such a factor.

In order to improve the accuracy of the emission inventory gathered at St. Louis, a number of representative sources were sampled and their stack effluents analyzed. An attempt was made to encompass a wide variety of the larger point sources: large and medium sized power plants burning coal, fuel oil and gas; industrial boilers of different types and sizes; and industrial operations, such as catalyst recovery units in a petroleum refinery, known or suspected of being major sources of pollution.

The program is an ongoing one; during 1975, the following sources were sampled:

Illinois Power's Wood River Power Plant

- Boiler No. 1, operated on gas
- Boiler No. 1, operated on fuel oil
- Boiler No. 4, operated on coal

Highland Power Plant, Highland, Illinois

- Boiler No. 3, operated on coal

Stag Brewery, Belleville, Illinois

- Boiler No. 1, operated on coal

General Motors Power Plant, St. Louis

- Boiler No. 2, operated on coal

Amoco Refinery, Hartford, Illinois

- Boiler No. 6, operated on oil and gas
- Catalyst Regeneration Unit

Complete stack sampling reports are attached as Appendix II.

4.2 DISCUSSION: METHODS AND RESULTS

In general, the test methods specified in the Appendix of Part 60, CFR Title 40, "Standards of Performance for New Stationary Sources" were used. The methods include:

Method 1 - Sample and Velocity Traverses
2 - Determination of Stack Gas Velocity
3 - Gas Analysis for CO_2, Excess Air and Dry Molecular Weight
4 - Determination of Moisture in Stack Gases
5 - Determination of Particulate Emissions
6 - Determination of SO_2 Emissions
7 - Determination of Nitrogen Oxide Emissions

The only deviation from these methods was the use of a higher probe and oven temperature in Method 5. A temperature of 325° was used instead of 250°F to avoid any problems with condensation of sulfuric acid.

Serious problems were encountered with stack gas velocity measurements using Method 2. Using mass balance methods as a check, it became apparent that the values obtained with an S-type pitot tube, used in accordance with Method 2, were too high by varying, but substantial amounts. Reproducibility was adequate, and repeated calibration of the pitot tube indicated that correct readings were obtained. A careful check of the literature indicated that high readings had been observed by other investigators. Burton (1) indicated that values of 104 to 150% of the rated value can be obtained. Grove (2) presented data indicating that a) significant errors are always positive and b) they can be very large. The most common source of errors is due to cyclonic flow, unfortunately a fairly common occurrence in power plant stacks, where "double entry" stacks (two boilers feeding one stack) are frequently used.

TABLE 1

COMPARISON OF MEASURED* and CALCULATED** FLOWS

Location	Flow, SCFH		% Δ
	Measured	Calculated	
Wood River #1	10,086,750	8,237,263	+22.5
Wood River #4	17,981,280	13,089,200	+37.4
Highland Power	1,386,070	910,920	+52.2
Stag Brewery	1,394,990	782,900	+78.2
Monsanto	1,687,655	1,563,000	+ 8.0
General Motors	1,598,005	1,434,047	+11.4
Amoco	2,543,040	-	-

* Using S-type Pitot tube, EPA Method 2
** Based on stoichiometry and excess air.

(1) Burton, C.S., Quantitation of Stack Gas Flow, Jnl., APCA 22, pp. 631-635 (1972).

(2) Grove, D.J. and Smith, W.S., Pitot Tube Errors due to Misalignment and Non-streamlined Flow, Stack Sampling News, 1974.

One way of ascertaining the correctness of the data is by comparing the mass flow of SO_2 calculated from fuel consumption and sulfur analysis of the fuel, on one hand, with the value obtained from stack gas flow and analysis, on the other. The former is calculated according to Eq. 1

$$W_{SO_2} = W_c \times 38 \times S \quad , \qquad (1)$$

where

W_{SO_2} = weight of SO_2 produced, lbs/hr

W_c = weight of coal consumed, Tons/hr

S = % sulfur in coal, dry basis

This value should be equal to one obtained from EQ. 2

$$W_{SO_2} = C_{SO_2} \times Q_S \quad , \qquad (2)$$

where

C_{SO_2} = Concentration of SO_2 in stack gas, lbs./SCF

Q_S = Stack gas flow rate, SCF/hr

For example, the flow rate for Boiler #4 at Wood River was calculated thusly:

Composition of Coal		Boiler #4 Lb-mols/100 lbs Coal		Oxygen Required For Combustion, mols
C	61.43%	5.12	(1)	5.12
H_2	4.38	(2.19)	(2)	(1.09)
S	3.21	0.10	(3)	0.10
O_2	9.67	0.30		-.30
N_2	1.11	0.04	(4)	-
H_2O (moisture)	11.82	(0.66)	(2)	-
Ash	8.55			
Chlorides	0.02			
	100.19			6.01 mols oxygen

Average Excess Air: 40% 2.40

Total 8.41

Corresponding Nitrogen 31.77

Assumed reactions:

(1) $C + O_2 \rightarrow CO_2$

(2) Excluded from calculation for dry flue gas

(3) $S + O_2 \rightarrow SO_2$

(4) Oxidation reaction uncertain

Dry flue gases per 100 lbs coal, lb-mols:

CO_2	5.12	
SO_2	0.10	lb-mol x 386 = SCF
O_2	2.40	
N_2	0.04	
Air Nitrogen	31.77	
Total	39.43	= 15,220 SCF/100#
@ 43 tons coal/hour		= 13,089,200 SCF#

A comparison of results is shown in Table 2. As can be seen from Table 2, the values obtained using flow rates based on mass balance show a much better agreement with values obtained from emission factors, than those based on pitot measurements.

TABLE 2

COMPARISON OF SO_2 EMISSIONS BASED ON CALCULATED AND MEASURED FLOWRATES

Location	W_{SO_2} - Weight of SO_2 Produced, Based on		
	Emission Factor	Calc. Gas Flow	Measured Gas Flow
Wood River #1 (oil)	153 lbs/hr	178 lbs/hr	217 lbs/hr
Wood River #4	5245	5104	7035
Highland Power	414	433	658
Stag Brewery	75	82	125
General Motors	479	472	546
Amoco (boiler)	309	*	320
(catalytic cracker)	708	*	354

For this reason, calculated flow rates were used whenever there was an indication of non-linear flow in the stack, as indicated by the fact that turning the pitot tube 90° on axis did not give a zero reading on the manometer.

Using the most reliable available results, experimental emission factors were calculated for SO_2, NO_x and particulates for the sources tested so far. These emission factors are compared with "standard" emission factors, taken from AP-42, in Table 3. Calculations are shown in Appendix I.

TABLE 3

COMPARISON OF "STANDARD" AND EXPERIMENTAL EMISSION FACTORS

Location	Standard Emission Factors					Experimental Emission Factors				
	SO_2*	NO_x	Part**	CO	HC	SO_2*	NO_x	Part**	CO	HC
Wood River #1 (gas fired)[1]	-	600	10	17	1	-	165	-	2.8	-
#1 (oil fired)[2]	1445	105	8	3	2	1685	16	1.8	.4	.17
#4 (coal fired)[3]	385	18	178	1	0.3	375	1.4	10.38		.02
Highland Power (coal fired)[3]	385	15	58	2	1	405	4.1	.48		
Stag Brewery (coal fired)[3]	385	15	58	2	1	415	7.2	1.58	.3	.38
General Motor (coal fired)[3]	385	15	138	2	1	375	10.8	21.6	.7	.05
Amoco[2] Boiler #6	1605	69	22	1	.3	-	-	-	-	-
Cat. Cracker Recovery[4]	493	71	242	-	220	246	153	360	-	.48

*S - percentage sulfur in fuel

**A - percentage ash in fuel; emissions before control equipment

(1) - lbs per 10^6 cu. ft.

(2) - lbs. per 10^3 gal. Both process gas and fuel oil were burned simultaneously.

(3) - lbs. per ton of coal

(4) - lbs. 10^3 bbl fresh feed.
Unit equipped with electric precipitator and CO boiler -

Even though relatively few source tests have been run so far, certain conclusions can be drawn from the results obtained:

1. Determinations of stack gas volumes according to EPA Method 2 is uncertain. Incorrect results are obtained in a high number of cases, since the basic assumption of laminar flow, parallel to the walls of the stack does not pertain in many cases.
2. Engineering calculations of mass flow, based on ultimate analysis of the fuel and determinations of the excess air in the stack gases, give reasonably accurate results. This is borne out by sulfur balance calculations. For example, the average experimental emission factors for SO_2 for coal burning installations comes out to 38.75S compared with 38S suggested in AP-42.
3. The emission factors shown in Table 3 are applicable to the specific installations for which they were obtained. However, definite patterns appear to exist, which seem to have more general validity:
    a) Emission factors for NO_x for combustion sources appear to be too high by a variable, but substantial margin. The experimentally obtained factors range from a low of 7.7% to 72% of the applicable AP-42 factors.

    b) Experimental emission factors for particulates similarly vary from 8 to 58% of the applicable AP-42 factors for installations which do not have precipitators. In the presence of the latter, their assumed efficiency becomes an overriding factor.

    c) Hydrocarbon and CO emissions, which are rather insignificant for combustion sources, likewise run less than suggested by AP-42 factors.

5.0 CONCLUSIONS

The RAPS Point Source Emission Inventory has produced an extensive and accurate data base with an hourly resolution for the base year of 1975, with a temporal resolution of 1 hour for the important point sources in the AQCR-70.

The emission factor verification program, though somewhat limited in scope, indicates that good accuracy can be expected from the SO_2 inventory. Estimates for oxides of nitrogen and particulates appear to be on the high side and may have to be adjusted by changes in the emission factors.

The continuation of the program for another year will do much in improving the definition of the data obtained so far.

APPENDIX I
EMISSION FACTOR CALCULATIONS

EMISSION FACTOR CALCULATIONS

WOOD RIVER #1 - GAS FIRED

Burn Rate: 580 x 10^3 SCF/hr   Sulfur: -   Ash: -   Flow Rate: 8,237,280 SCFH

NO_x expected .580 x 600 = 348 lbs/hr
found: 7.4 x 10^6 lbs/SCF (average)
7.4 x 10^6 x 8,257,280 = 60.9 lbs.

Experimental EMFAC: $600 \times \frac{60.9}{348} = 105$

CO expected: .580 x 17 = 9.9 lbs/hr
found: 2.5 ppm
$2.5 \times 10^6 \times 8{,}237{,}280 \times 28.3 \times \frac{28}{22.4} \times 2.205 \times 10^3 = 1.6$ lb/hr

Experimental EMFAC: $17 \times \frac{1.6}{9.9} = 2.76$

WOOD RIVER #1 - OIL FIRED

Burn Rate: 3.66 x 10^3 gal/hr   Sulfur: .29% Ash: -   Flow Rate: 8,237,263 SCFH

SO_2 expected: 3.66 x 144 x .29 = 152.8 lbs/hr
found: 178.0 lbs/hr

Experimental EMFAC: $144 \times \frac{178}{152.8} = 167.7$

NO_x expected: 3.66 x 105 = 384.3 lbs/hr
found: 7.1 x 10^6 x 8,237,263 = 58.5 lbs/hr

Experimental EMFAC: $105 \times \frac{58.5}{384.3} = 16.0$

EMISSION FACTOR CALCULATIONS

CO expected: $3.66 \times 3 = 11.0$ lbs/hr
found: $2.5 \times 10^{-6} \times 8{,}237{,}265 \times \frac{28.3}{22.4} \times \frac{28}{454} = .635 = 1.6$ lbs/hr

Experimental EMFAC: $3 \times \frac{1.6}{11.0} = .44$

PARTICULATE expected: $3.66 \times 8 = 29.3$ lbs/hr
found: $4.55 \times 10^{7} \times 8{,}237{,}263 = 3.7$ lbs/hr

Experimental EMFAC: $8 \times \frac{3.7}{29.3} = 1.0$

HC expected: $3.66 \times 2 = 7.3$ lbs/hr
found: 1.7 ppm
$1.7 \times 10^{-6} \times 8{,}237{,}263 \times \frac{28.3}{22.4} \times \frac{16}{454} = .635$ lbs/hr

Experimental EMFAC: $2 \times \frac{.635}{7.3} = .17$

WOOD RIVER #4 - COAL FIRED

Burn Rate: 43 T/hr Sulfur: 3.21% Ash: 10.95% Flow Rate: 13,089,200 SCFH

SO_2 expected: 5245 lbs/hr
found: 5104 lbs/hr

Experimental EMFAC: $38 \times \frac{5104}{5245} = 36.97$

NO_x expucted: $18 \times 43 = 774$ lbs/hr
found: 4.46×10^{6} lb/SCF
$4.46 \times 10^{6} \times 13{,}089{,}200 = 58.37$ lbs/hr

Experimental EMFAC: $18 \times \frac{58.4}{774} = 1.36$

EMISSION FACTOR CALCULATIONS

Particulates: expected: 43 x 17 x 10.95 = 8004 lbs/hr
Less: Precipitator at 99.5% off = 7964
40 lbs/hr
found: 23.45 lbs/hr

Experimental EMFAC: $17 \times \frac{23.5}{40} = 9.96$

HC expected: 43 x .3 = 12.9 lbs/hr
found: 1.3 ppm
$1.3 \times 10^{6} \times 13,089,200 \times \frac{28.3}{22.4} \times \frac{16}{454} = .76$ lbs/hr

Experimental EMFAC: $.3 \times \frac{.76}{12.9} = 0.018$

HIGHLAND POWER COMPANY

Burn Rate: 6702 lbs/hr 3.25% Sulfur 10.98% Ash Flow Rate: 910,920

SO_2: expected: 414 lbs/hr
found: 433 lbs/hr

Experimental EMFAC: $38 \times \frac{433}{414} = 39.7$

NO_x: expected: $\frac{6702}{2000} \times 15 = 50.26$ lbs/hr
found: $1.5 \times 10^{6} \times 910,920 = 13.66$ lbs/hr

Experimental EMFAC: $15 \times \frac{13.7}{50.3} = 4.1$

Particulates: expected $\frac{6702}{2000} \times 5 \times 1.95 = 183.5$ lbs/hr
found: $1.76 \times 10^{6} \times 910,920 = 16$ lbs/hr

Experimental EMFAC: $5 \times \frac{16}{183.5} = 0.44$

EMISSION FACTOR CALCULATIONS

STAG BREWERY

Burn Rate: 3604 lbs/hour   Sulfur: 3.25%   Ash 10.98%   Flow Rate: 782900 SCFM

SO_2 expected: 74.9   81.4 lbs/hr
founded: 79.0   91.1 lbs/hr

Experimental EMFAC: $38 \times \frac{79}{74.9} = 40.1$ $38 \times \frac{91.1}{81.4} = 42.5$

NO_x expected: $\frac{3604}{2000} \times 15 = 27.0$ lbs/hr
found: 1.65×10^5 lbs/SCF
$1.65 \times 10^5 \times 782{,}900 = 12.9$ lbs/hr

Experimental EMFAC: $15 \times \frac{12.9}{27} = 7.16$

Particulates expected: $\frac{3604}{2000} \times 5 \times 10.98 = 98.9$ lbs/hr
found: 37 lbs/hr

Experimental EMFAC: $5 \times \frac{37}{98.9} = 1.87$

Hydrocarbons: expected: $\frac{3604}{2000} \times 1 = 1.8$ lbs/hr
found. 7 ppm
$782{,}900 \times 7 \times 10^6 \times \frac{28.3}{22.4} \times \frac{16}{454} = .24$ lbs/hr

Experimental EMFAC: $1 \times \frac{.24}{1.8} = .14$

CO expected: $1.802 \times 2 = 3.6$ lbs/hr
found: 8.9 ppm = .54 lbs/hr

Experimental EMFAC: $2 \times \frac{.54}{3.6} = .30$

EMISSION FACTOR CALCULATIONS

GENERAL MOTORS

SO_2 expected: 479 lbs/hr

found: 472 lbs/hr

Experimental EMFAC: $38 \times \frac{472}{479} = 37.4$

NO_x expected: $\frac{7491}{2000} \times 15 = 56.2$ lbs/hr

found: $2.81 \times 10^{5} \times 1{,}434{,}847 = 40.3$ lbs/hr

Experimental EMFAC: $15 \times \frac{40.3}{56.2} = 10.8$

Particulates expected: $\frac{7491}{2000} \times 13 \times 10.9 = 531$ lbs/hr

less: Precipitation at 98% $\frac{520}{11}$ lbs/hr

found: $1.396 \times 10^{5} \times 1{,}434{,}847 = 20.0$ lbs/hr

Experimental EMFAC: $13 \times \frac{20}{11} = 23.6$

CO expected: $\frac{7491}{2000} \times 2 = 7.5$ lbs/hr

found: $1{,}434{,}847 \times 25 \times 10^{6} \times \frac{28.3}{22.4} \times \frac{28}{454} = 2.8$ lbs/hr

Experimental EMFAC: $2 \times \frac{2.8}{7.5} = .74$

HC expected: $\frac{7491}{2000} \times 1 = 3.8$ lbs/hr

found: $1{,}434{,}847 \times 1.8 \times 10^{6} \times \frac{28.3}{22.4} \times \frac{16}{454} = .11$ lbs/hr

Experimental EMFAC: $1 \times \frac{.11}{3.8} = .03$

EMISSION FACTOR CALCULATIONS

AMOCO - BOILER #6

Burn Rate: 64,063 SCF/H Refinery Gas 300 gal/hr Fuel Oil Sulfur 3.5%
Flow Rate: 21,453,040 1.4%

SO_2 expected: 64.063 x 3.5 x 1.069* = 239.7 *Spec. Emission Factor
.300 x 1.4 x 160 = 68.9
308.6

found: 1.26 x 10^{4} x 2,543,040 = 320.2 lbs/hr

AMOCO - CATALYTIC CRACKER RECOVERY

Feed Rate: 34,485 bbl/day fresh feed Flow Rate: 5,160,271

SO_2 expected: 34.485 x 493 x $\frac{1}{24}$ = 708 lbs/hr

found: 5,160,271 x 6.853 x10^{5} = 353.6 lbs/hr

Experimental EMFAC: 493 x $\frac{354}{708}$ = 246.3

NO_x expected: 34.485 x 71 x $\frac{1}{24}$ = 102.0 lbs/hr

found: 4.26 x 10^{5} x 5,160,271 = 219.8 lbs/hr

Experimental EMFAC: 71 x $\frac{220}{102}$ = 153

Particulates expected: 34,485 x 242 x $\frac{1}{24}$ = 347.7 lbs/hr

less precipitator at 95% 327.9
19.8

found: 29.5 lbs/hr

Experimental EMFAC: 242 x $\frac{29.5}{19.8}$ = 360

HC expected: $34,485 \times 220 \times \frac{1}{24} = 316.1$ lbs/hr

found: $5,160,271 \times 3 \times \frac{28.3}{22.4} \times \frac{16}{454} = .69$ lbs/hr

Experimental EMFAC: $220 \times \frac{.69}{316.1} = .48$

APPENDIX II

SOURCE TEST REPORTS

SOURCE TEST REPORT
ILLINOIS POWER COMPANY
WOOD RIVER PLANT
ALTON, ILLINOIS
BOILERS NO. 1 AND 4

JUNE, 1975

Tested by: Rockwell International

S.W. Griscom
D.C. Klein
F.E. Littman
W.G. Norris
R.R. Ducker

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1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report details the results obtained on boilers No. 1 and 4 at the Wood River Plant of the Illinois Power Company.

The stack testing included the following pollutants: SO_2, particulates, NO_x, H_2SO_4, and hydrocarbons. Orsat analysis for CO_2, CO, and O_2 were also performed. Detailed results are included in this report. Although these tests were not conducted to ascertain compliance with Illinois standards, it is of interest that the emissions were well within limits, with the exception of SO_2 emissions from the coal fired boiler No. 4.

We acknowledge and appreciate the excellent cooperation we obtained from both local and home office representatives of Illinois Power Co.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the Illinois Power Co.-Wood River Plant in Alton, Illinois. Testing was performed on boiler No. 1 during natural gas and oil firings and on boiler No. 4 during coal firing. The test on boiler No. 1 was during the week of 16 June 1975 and the test on boiler No. 4 was during the week of 23 June.

Boiler No. 1 is a gas and/or oil fired, 450,000 pounds per hour steam generating unit. There are no stack emission controls on boiler No. 1. Boiler No. 4 is a pulverized coal fired, 713,000 pounds per hour steam generating unit. There are mechanical and electrostatic precipitators on boiler No. 4.

Both units were sampled for total particulates, nitrogen oxides, hydrocarbons, sulfur dioxide, sulfuric acid mist, carbon dioxide and oxygen. Boiler No. 4 was also sampled for particle size distribution.

3.0 PROCESS DESCRIPTION

Boiler No. 1 was built by Combustion Engineering and installed in 1949. It was originally operated as a pulverized coal fired unit but was converted to gas and/or oil fired. The unit is rated at 450,000 lbs per hour steam at 1325 psi and 1010°F. Boiler No. 1 is a forced draft unit and it has no stack emission controls. This boiler is illustrated in Figure 1. Boilers 1, 2 and 3 are similar units and are served by a common stack. The stack is of brick construction, 250 ft tall and 15.5 ft inside diameter at the top.

Boiler No. 4 was built by Combustion Engineering and installed in 1954. It is a pulverized, coal-fired steam generating unit. The unit is rated at 713,510 lbs per hour at 1500 psi and 1005°F. The boiler is an induced draft type and it is equipped with centrifugal and electrostatic precipitators, rated at 99.5% collection efficiency. This boiler is illustrated in Figure 2.

Boiler No. 4 is served by a brick stack, 250 ft tall and, 17 ft inside diameter at the top.

There is a Monsanto CATOX, sulfur dioxide scrubber installed on unit No. 4 adjacent to the electrostatic precipitator. This unit is currently not in operation and should have no effect on this source test.

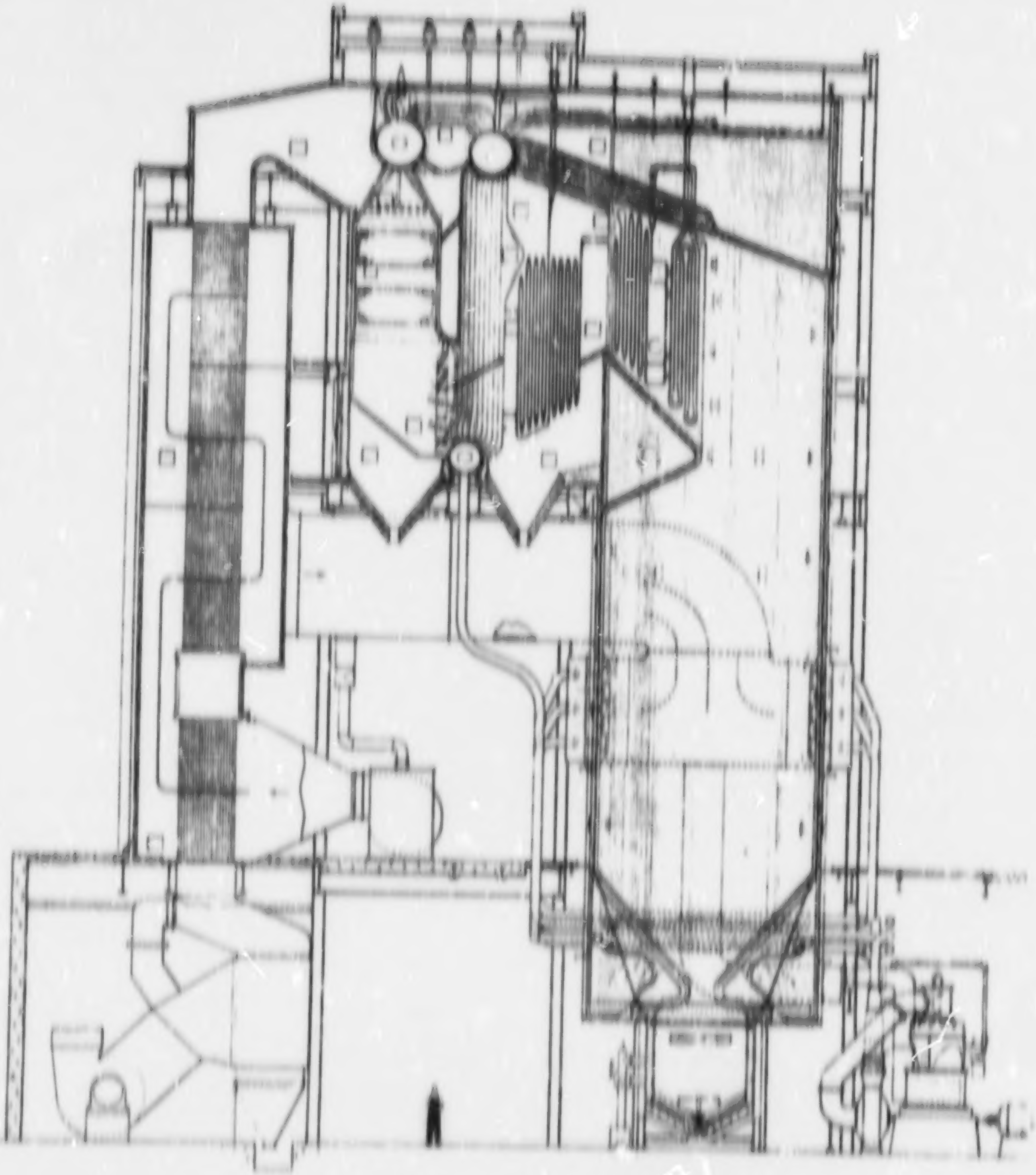

FIGURE 1 - BOILER NO. 1

C-E STEAM GENERATING UNIT

MAX. CONT. CAP. - 450,000 LB PER HR AT 1800 PSI AND 1010 F TOTAL TEMP.

WOOD RIVER POWER STATION

Illinois Power Company, Wood River, Ill.

DESIGNED AND BUILT BY COMBUSTION ENGINEERING - SUPERHEATER, INC.

SARGENT & LUNDY, Consulting Engineers

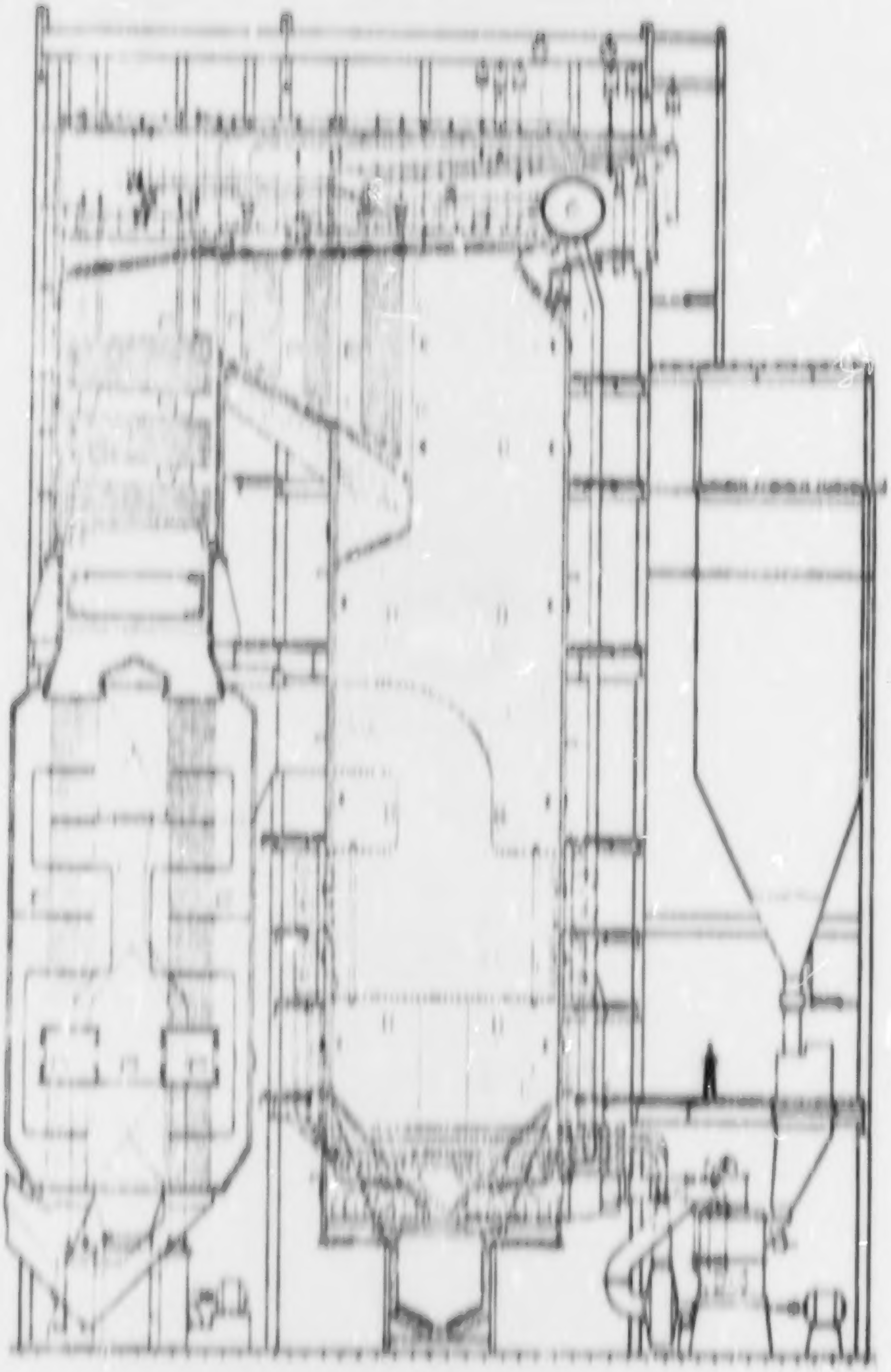

FIGURE 2 - BOILER NO. 4
C-E REHEAT STEAM GENERATOR
CAPACITY - [illegible]
WOOD RIVER POWER STATION
Illinois Power Company Wood River, Ill.
Designed and Built by COMBUSTION ENGINEERING SUPERHEATER INC
SARGENT & LUNDY, Consulting Engineers

4.0 SOURCE TEST DESCRIPTION

Boiler No. 1 was tested in the duct work, just ahead of where the duct combines with flow from Boiler No. 2 (see Figure 3 below).

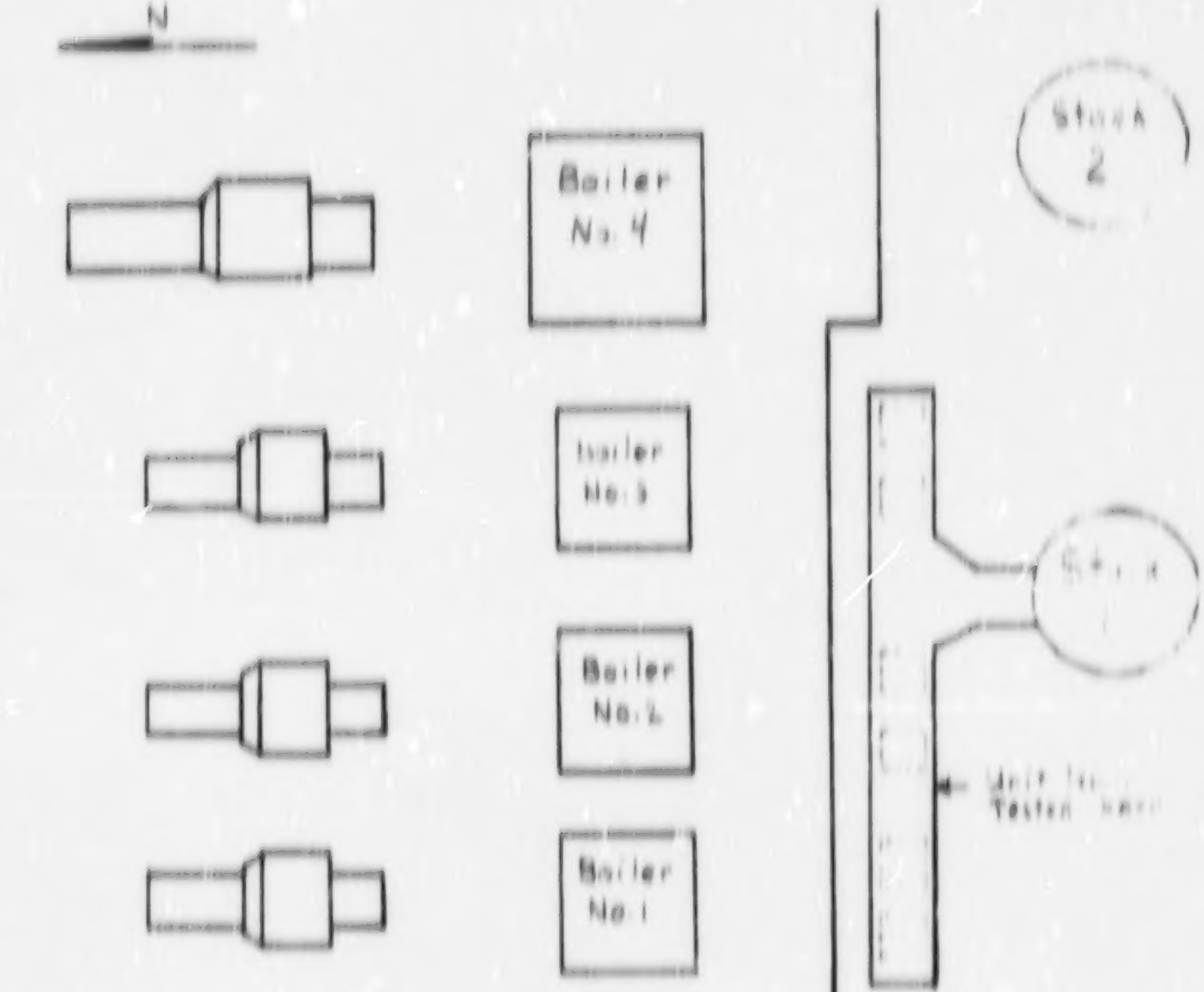
N
Stack 2
Boiler No. 4
Boiler No. 3
Boiler No. 2
Boiler No. 1
Stack 1
Unit No. 1 Tested here

FIGURE 3 - WOOD RIVER PLANT, PLOT PLAN

At this sampling point the duct is 7'1" x 11'6 5/8" inside dimensions. To obtain forty-two sampling points, eight, 3 inch sampling ports were welded in place, approximately 17 1/2 inches apart vertically and six points were sampled at each port. This sampling point is only 1-2 duct diameters from the nearest induced draft fan outlet and is therefore not an ideal spot for sampling, but it is the best available location for testing this boiler without going to the large expense of constructing a sampling platform on the stack.

As it turned out, the bottom sampling port was at the same level as the build-up of particulates in the duct. The inside duct dimensions are then revised for this point to 7'1" x 10'6 5/8".

Figures 4 and 5 illustrate the sampling location and arrangement for this test.

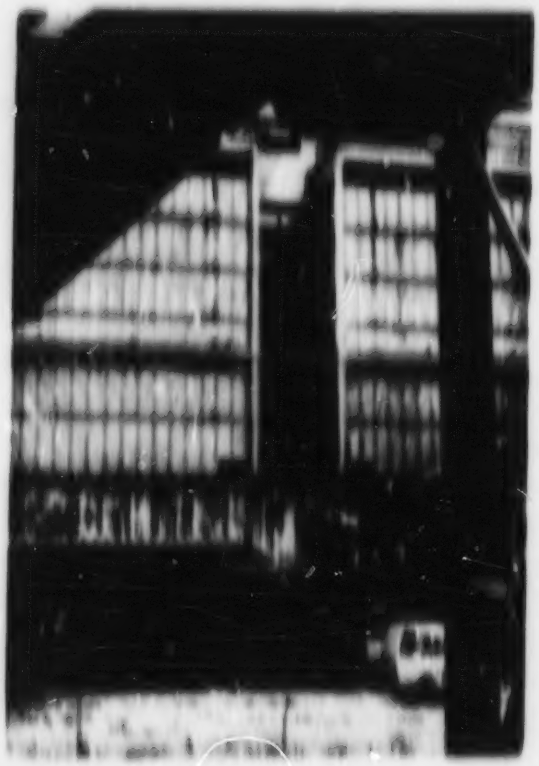

FIGURE 4

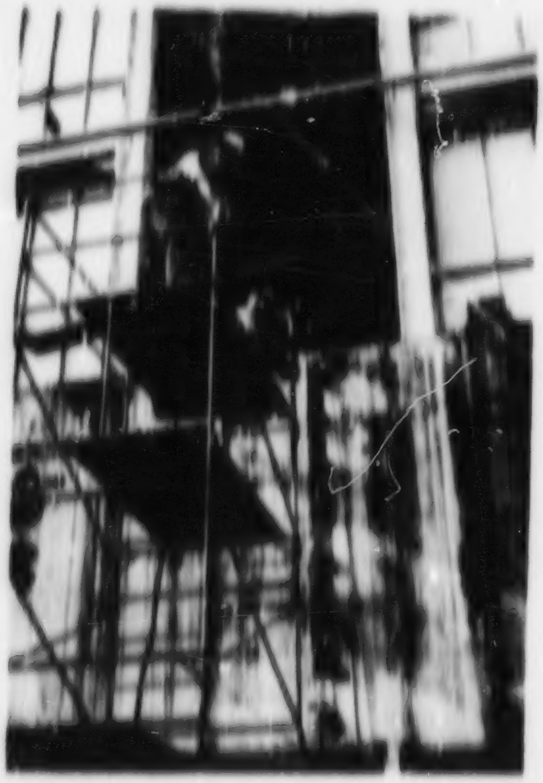

FIGURE 5

The test on boiler No. 4 was performed on a platform on the stack at roof top level, approximately 140 feet above ground level. This platform was installed for the testing of this unit in conjunction with the evaluation of the CATOX scrubbing system. There is a ramp connecting this platform to the roof of the power plant building.

At this level there are four 6 inch ports installed at 90 degrees around the stack. At each of these points on the platform, there are extensions to the platform to allow for a good working area and for set-up and supporting sampling equipment. An adapter was made to give us a 3 inch coupling to attach to for our supporting monorail.

At this location the stack diameter is 24.75 feet and it is approximately four diameters from the inlet to the stack. A full traverse of the stack was performed with eighteen sampling points on the traverse.

Figures 6 and 7 illustrate the sampling location and set-up for this test.

FIGURE 6

FIGURE 7

4.0 PROCESS OPERATION

Boiler No. 1 was tested 17 June to 20 June. On 17 and 18 June, the boiler was fired with natural gas only and on 19 June and 20 June the boiler was fired with distillate oil only. During testing periods on all four days the boiler was under constant load of 420,000 lbs per hour steam. There was only one short fluctuation for approximately 30 minutes on 19 June when some oil burners malfunctioned. Only one time was there any excessive emissions from stack No. 1 and this was due to an unbalanced fuel/air ratio in getting boiler No. 1 up to full load prior to our testing.

Boiler No. 4 was tested from 24 June to 27 June. During this entire sampling period the load on this boiler was maintained almost constant, with a generator output of 100 MW. There were no noticeable excessive emissions during this period. Ashes are blown from the boiler at approximately 10:30 AM and 3:00 PM. There was no visible change in emissions during these periods, although the actual amount of particulates apparently increased as shown by our particle size testing before and during this time period.

6.0 DISCUSSION

The EPA standard method 2, Volumetric Flow Rate Determination, has come under question as a result of this testing. On boiler No. 1 the flow rate as determined by method 2 is 168,113 SCFM compared to a flow rate determined stoichiometrically from the fuel rate and fuel composition of 137,288 SCFM. At the sampling point for boiler No. 1, method 2 was not applied precisely since only 42 points were used instead of perhaps 48 or 50 due to the bottom port being blocked, but by observing the values that were obtained it is unlikely that more sampling points would bring these two flow rates into agreement.

On boiler No. 4 the average flow rate determined by method 2 is 299,688 SCFM compared to an average flow rate of 218,497 SCFM determined stoichiometrically. At the sampling point for boiler No. 4 only one complete traverse was made per test instead of two on perpendicular diameters as described in method 2. Despite this, the values obtained corresponded with values obtained by other testers of this unit, so it is felt that this test is a valid measurement using method 2.

The flow rate determined stoichiometrically compares very well with the expected flow as seen by a comparison of sulfur dioxide emissions using both flow rates. Using the published emission factor of 38 S, which allows for a 95% conversion of sulfur in the coal to sulfur dioxide emission, the emissions should be 5245 lb/hr. With the flow rate using method 2 the emissions would be 6689 to 7318 lb/hr, which is definitely too great. With the stoichiometric flow rate the emissions would be 4877 to 5335 lb/hr, which is a reasonable result. For this reason the emissions determined using the stoichiometric flow rate are reasoned to be the correct results. For comparison the emissions are expressed using both flow rates.

On boiler No. 4 the coal scales were not functioning during the test period. The fuel firing rate of 43 tons per hour was determined by comparing the operating conditions with similar conditions on record as part of the ongoing emission inventory.

7.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods.

Gas flow rates were calculated using the observed gas temperature, molecular weight, pressure and velocity, and the flow area. The gas velocity was calculated from gas velocity head measurements made with an S-type pitot tube and a magnehelic pressure gauge, using standard method 2.

Moisture contents were determined by passing a measured amount of gas through chilled impingers containing a known volume of deionized water, measuring the increase in volume of the impingers liquid and the increase in weight of silica gel used to finally dry the gas, and calculating the amount of water vapor in the sample from this increase and the measured amount of gas.

The stack gas concentrations of carbon dioxide, oxygen, carbon monoxide, and nitrogen by difference were measured with a standard Orsat apparatus. These concentrations and the moisture content were used to determine molecular weight of the stack gas.

7.1 PARTICULATE MATTER

Standard method 5 was used for determining particulate emissions with the exception that the probe and oven were operated at 300-350^{0}F. Measured stack gas samples were taken under isokinetic conditions. The samples were passed through a cyclone, fiberglass filter, impingers, pump, a meter and an orifice as shown in Figure 8.

The total particulate matter collected in each test was the sum of the filter catch plus material collected ahead of the filter in the sampling train. The amount of filter catch is determined by the difference in the weight of the filter before and after the test, after dessicating. The particulate matter from other portions of the train were determined by rinsing the probe, cyclone and all glassware ahead of the filter with acetone, evaporating to dryness and weighing.

7.2 NITROGEN OXIDE

Using method 7, gas samples were withdrawn from the stack into evacu-

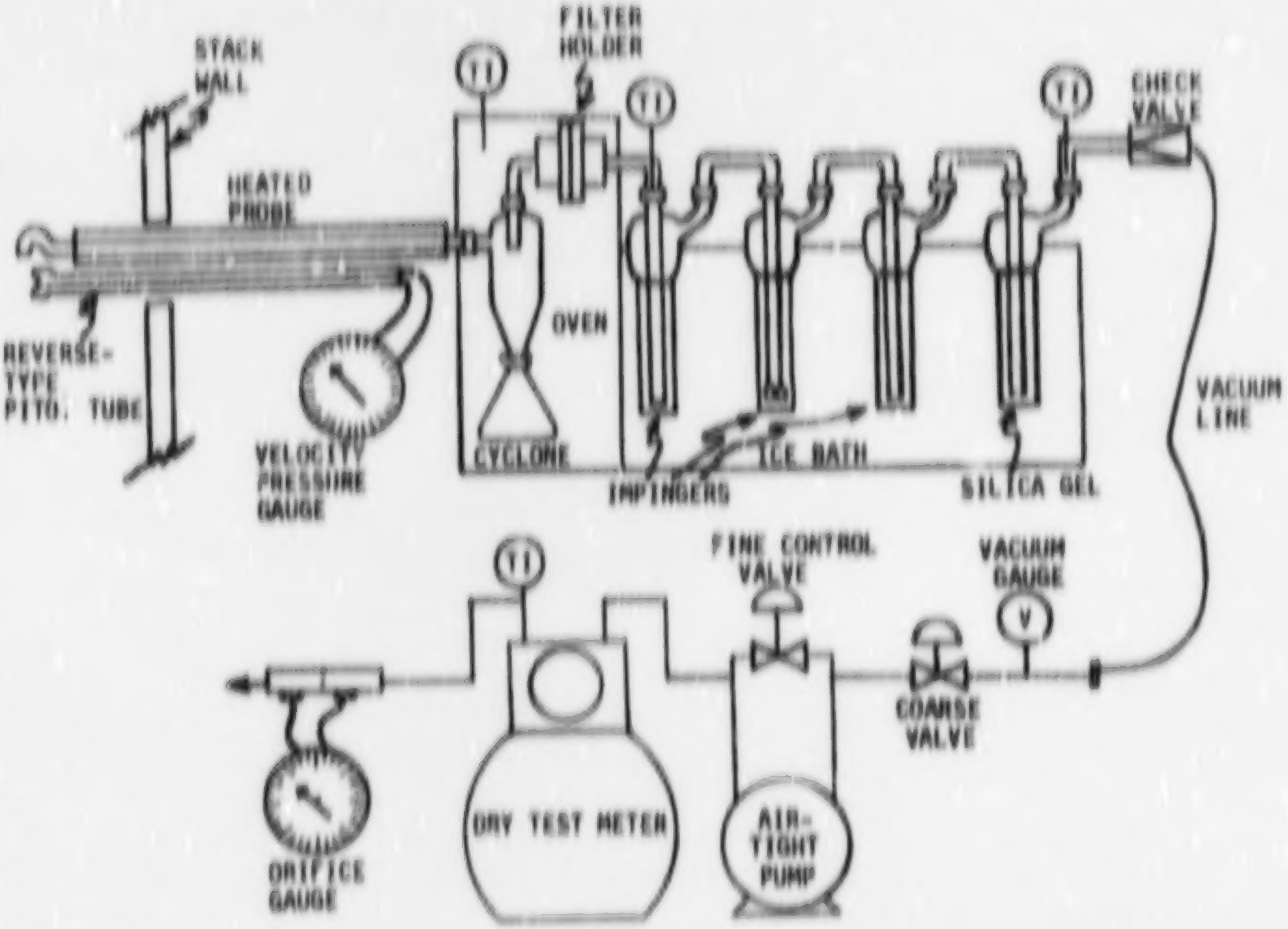
STACK WALL
FILTER HOLDER
TI
TI
TI
CHECK VALVE
HEATED PROBE
OVEN
REVERSE-TYPE PITO. TUBE
VELOCITY PRESSURE GAUGE
CYCLONE
IMPINGERS
ICE BATH
SILICA GEL
VACUUM LINE
TI
FINE CONTROL VALVE
VACUUM GAUGE
V
COARSE VALVE
DRY TEST METER
AIR-TIGHT PUMP
ORIFICE GAUGE

FIGURE 8

PARTICULATE SAMPLING TRAIN

ated 2-liter flasks containing a dilute solution of hydrogen peroxide and sulfuric acid. The hydrogen peroxide oxidizes the lower oxides of nitrogen (except nitrous oxide) to nitric acid. The resultant solution is evaporated to dryness and treated with phenol disulfonic acid reagent and ammonium hydroxide. The yellow trialkali salt of 6-nitro-1-phenol-2, 4-disulfonic acid is formed, which is measured colorimetrically.

7.3 SULFURIC ACID MIST AND SULFUR DIOXIDE

The "Shell Method"* was chosen for this determination due to uncertainties which exist about the validity of the results using method 8. A gas sample is drawn from the stack using a heated probe and passed through a water cooled, coil condenser maintained below the dew point of sulfuric acid at 140°-194°F, followed by a fritted glass plate and then passed through a chilled impinger train with two impingers containing an isopropanol and hydrogen peroxide mixture and followed by an impinger containing silica gel for drying. This set-up is shown in Figure 9.

The condensed sulfuric acid mist in the coil condenser is water washed from the condenser. The final determination is made by titrating the solution with barium chloride, using a thorin indicator. Isopropanol must be added to the solution to be titrated to improve the rapidity with which the barium sulfate precipitates during titration.

Sulfur dioxide in the gas sample is oxidized to sulfur trioxide the impingers containing the hydrogen peroxide. Sulfur dioxide is then determined by titrating the hydrogen peroxide solution with barium chloride, using a thorin indicator.

* Lisle, E.S. and J.D. Sensenbaugh, "The Determination of Sulfur Trioxide and Acid Dew Point in Flue Gases", Combustion, Jan. 1965.

Goksøyr, H. and K. Ross, "The Determination of Sulfur Trioxide in Flue Gases", J. Inst. Fuel, No. 35, 177, (1962).

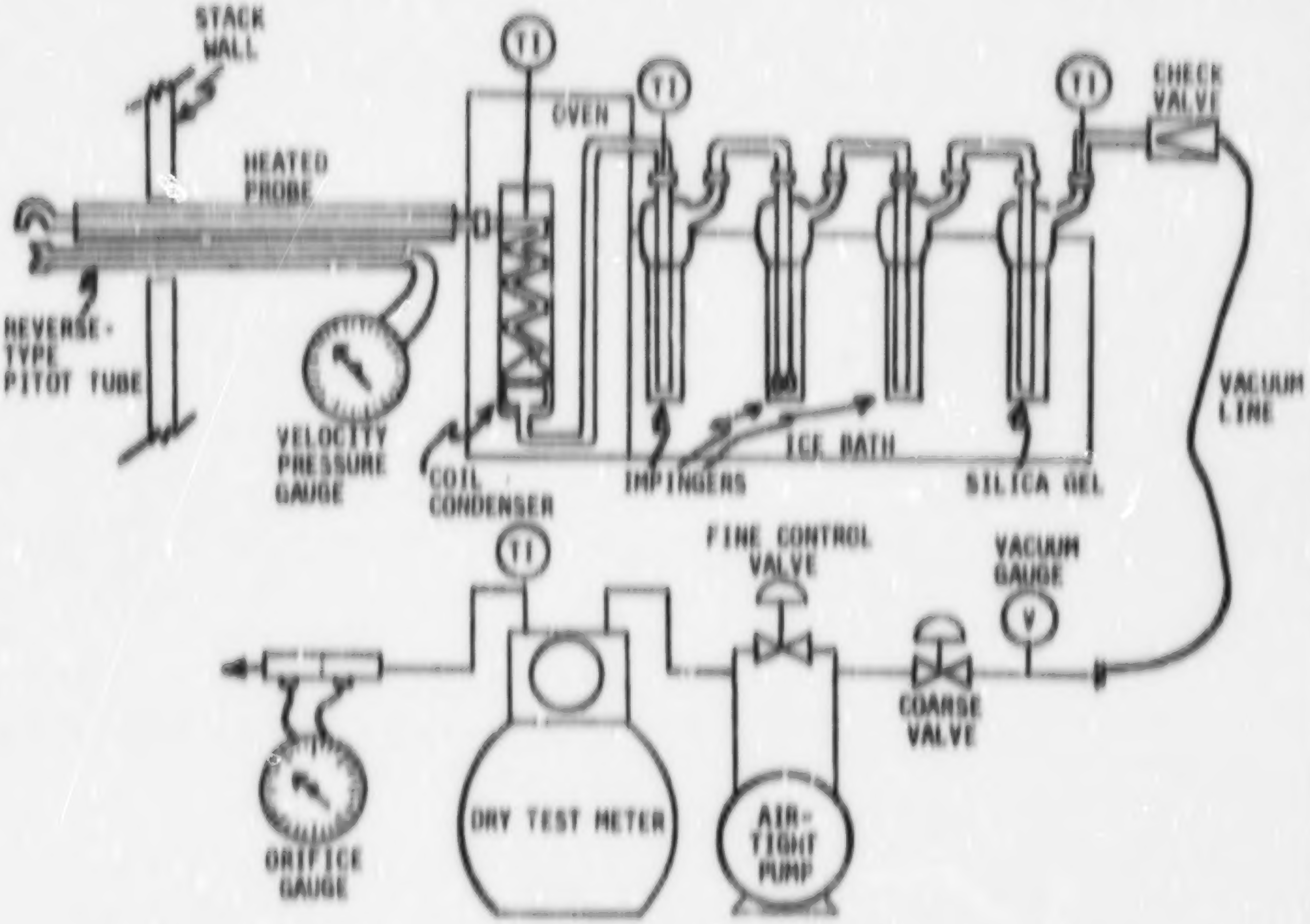
STACK WALL
HEATED PROBE
REVERSE-TYPE PITOT TUBE
VELOCITY PRESSURE GAUGE
TI
OVEN
COIL CONDENSER
TI
IMPINGERS
ICE BATH
SILICA GEL
TI
CHECK VALVE
VACUUM LINE
TI
FINE CONTROL VALVE
VACUUM GAUGE
V
COARSE VALVE
ORIFICE GAUGE
DRY TEST METER
AIR-TIGHT PUMP

FIGURE 9

SULFURIC ACID MIST SAMPLING TRAIN

7.4 PARTICLE SIZE

An Andersen, fractionating, inertial impactor is used for the determination of particle size in the range of approximately 0.5 to 10.0 microns. The sampling head is placed either in the stack at the end of the sampling probe or in the oven after the heated sample probe. A sample of stack gas is drawn isokinetically through the sampler (see Figure 10). The particulate matter is fractionated and collected on the plates inside the sample head and a determination is made by the difference in weight of the plates before and after testing. Results are expressed for particles of unit density.

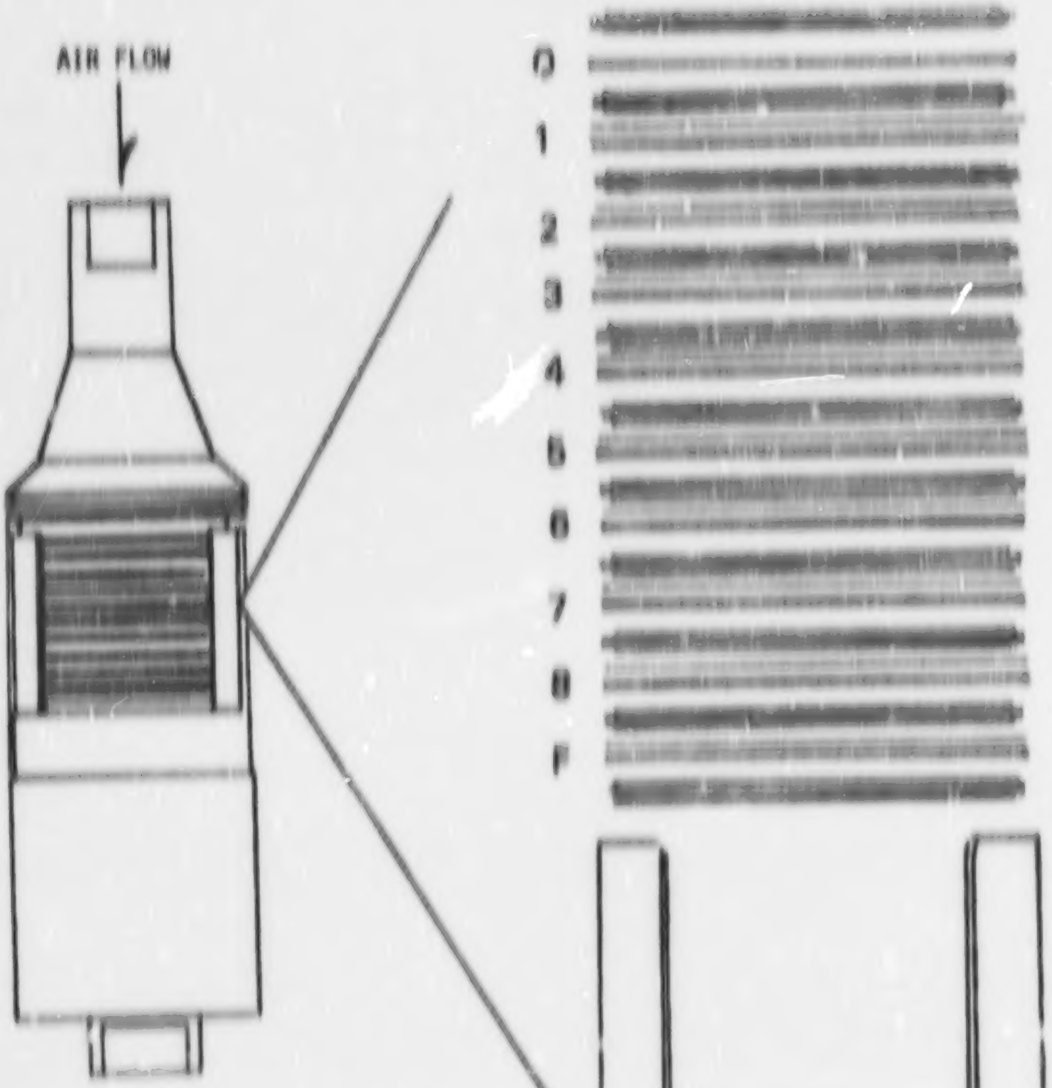
AIR FLOW
0
1
2
3
4
5
6
7
8
F

FIGURE 10
ANDERSEN STACK SAMPLER

8.0 RESULTS

The results obtained from these tests are summarized in Table 1 and 2. As discussed previously, the main flow of pollutant is based on calculated, rather than measured, flow rates. The actual calculations and field data are attached as Appendixes A and B. Although these tests were performed for research purposes and not as part of compliance procedures, standard EPA methods were used (except as indicated). It is thus of interest to compare the results obtained with State of Illinois standards. A comparison is shown in Table 3.

TABLE 1
Boiler No. 1
SUMMARY OF RESULTS

Date	6/18	6/19	6/20		
Stack Flow Rate - SCFM * dry		137,200			
% Water Vapor - % Vol.		10.1			
% CO_2 - Vol % dry		10.3			
% O_2 - Vol % dry		8.9			
% Excess air @ sampling point		70.7			
SO_2 Emissions - lbs/10^6 Btu			0.35		
NO_x Emissions - lbs/10^6 Btu	0.08	0.12	0.10		
H_2SO_4 Mist - lbs/10^6 Btu			0.01		
Particulates Probe, Cyclone, & Filter Catch					
lbs./hr.		3.7			
lbs/10^6 Btu		0.007			
Total Catch					
lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling		79.8			

*70° F, 29.92" Hg
Calculated flow, dry

TABLE 2
Boiler No. 4
SUMMARY OF RESULTS

Date	6/26	6/26	6/27		
Stack Flow Rate - SCFM * dry	218497	218,497	218,497		
% Water Vapor - % Vol.	8.26	8.16			
% CO_2 - Vol % dry	16.4	14.7	15.3		
% O_2 - Vol % dry	6.4	5.6	5.5		
% Excess air @ sampling point	45.3	35.9	35.3		
SO_2 Emissions - lbs/10^6 Btu		5.77	5.27		
NO_x Emissions - lbs/10^6 Btu	0.65	0.62			
H_2SO_4 Mist - lbs/10^6 Btu		0.05	0.05		
Particulates Probe, Cyclone, & Filter Catch					
lbs./hr.	29.8	17.1			
lbs/10^6 Btu	0.03	0.02			
Total Catch					
lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling	96.8	93.4			

*70° F, 29.92" Hg
Calculated Flow, dry

TABLE 3

COMPARISON OF RESULTS

Pollutant	Fuel	Standard $lbs/10^6$ Btu	Found $lbs/10^6$ Btu	Comment
SO_2	Gas	-----	--------	Boiler 1
	Oil (Dist)	0.3	0.35	Boiler 1
	Coal	1.8	5.52	Boiler 4
NO_x	Gas	0.3	0.08	Boiler 1
	Oil(Dist)	0.2	0.11	Boiler 1
	Coal	0.9	0.64	Boiler 4
Particulates	Gas	0.1		Boiler 1
	Oil	0.1	0.007	Boiler 1
	Coal	0.1	0.02	Boiler 4

Minor constituents are summarized in Table 4.

TABLE 4

MINOR CONSTITUENTS

	Boiler No. 1	Boiler No. 4
H_2SO_4 (mist)	0.01 lbs/10^6 Btu	0.09 lbs/10^6 Btu
CO	2.5 ppm (Avg)	
Hydrocarbon	1.7 ppm (Avg)	1.3 (Avg)

In addition to measuring particulate loadings, a particle size analysis was made using an Andersen impactor. The results are shown in Table 5 and Figure 11. The high percentage of particles less than 0.4 microns in diameter is probably spurious. Microscopic examination indicates the presence of large ammonium sulfate particles, which apparently were formed by subsequent reactions of ammonia with sulfuric acid. The latter, present in vapor form at stack temperature, was apparently retained by the glass fiber filter.

TABLE 5
PARTICLE SIZE DETERMINATION

Test: Run 1 Boiler #4 Date: 6/27

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	20.4745	20.4766	2.1			6.2	100.0	11.1 & above
2	21.4719	21.4753	3.4			10.0	93.8	6.95
3	21.6035	21.6073	3.8			11.2	83.8	4.65
4	22.8162	22.8195	3.3			9.4	72.6	3.25
5	11.7385	11.7412	2.7			8.0	63.2	2.05
6	11.4893	11.4915	2.2			6.5	55.2	1.05
7	11.7409	11.7418	0.9			2.7	48.7	0.64
8*	21.4087	21.4100	1.3			3.8	46.0	0.43
Back Up Filter				14.3		42.2	42.2	<0.43
		Total	19.6	14.3	33.9			

Test: Run 2 Boiler #4 Date: 6/27

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	20.1922	20.1955	3.3			7.7	100.0	11.1 & above
2	21.3713	21.3758	4.5			10.6	92.3	6.95
3	21.6884	21.6920	3.6			8.5	81.7	4.65
4	22.3725	22.3768	4.3			10.1	73.2	3.25
5	11.6966	11.7003	3.7			8.7	63.1	2.05
6	11.6809	11.6836	2.7			6.3	54.4	1.05
7	11.6868	11.6892	2.4			5.6	48.1	0.64
8*	20.9214	20.9219	0.5			1.2	42.5	0.43
Back Up Filter				17.6		41.3	41.3	<0.43
			25.0	17.6	42.6			

* Weighed after test, cleaned, tared

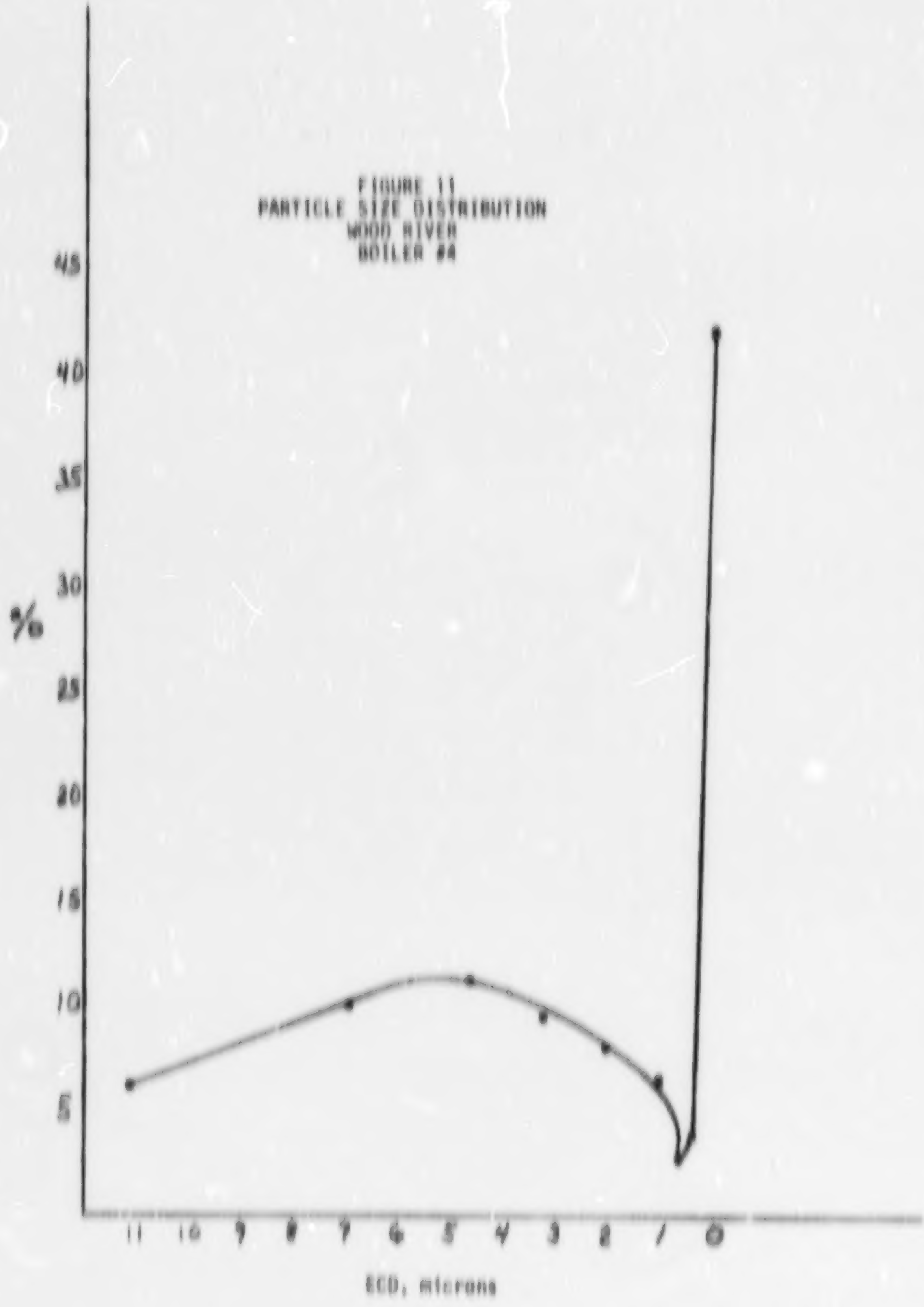

FIGURE 11
PARTICLE SIZE DISTRIBUTION
WOOD RIVER
BOILER #4

APPENDIX A
PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70° F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{CF_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530° R or 70° F

Tm = Meter temperature, 530° R for compensated meter

CFm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = Vl_c \left(\frac{\rho H_2O}{MH_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right) \frac{lb.}{454\ gm.} = 0.0474 \times Vl_c$$

Vw = Volume of water vapor at standard conditions, ft^3

Vl_c = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

$M\ H_2O$ = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - °R

% Moisture in Stack Gas

$$\%\ M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\% O_2 \times \frac{32}{100}\right) + \left(\% N_2 \times \frac{28}{100}\right)$$

Molecular weight of stack gas

$$MW_W = \left(\frac{100 - \% M}{100} \times MW_D\right) + \left(\frac{\% M}{100} \times 18\right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{T_s \times \Delta P\ avg.}{P_s \times MW_W}\right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{ft.}{sec.}\left(\frac{lb.}{lb.\ Mole - {}^{\circ}R}\right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, °R

$_s$ = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Q_s = 3600\left(1 - \frac{\% M}{100}\right) V_s\ A\left(\frac{T_{std}}{T_s}\ \frac{P_s}{P_{std}}\right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Q_s' = Q_s \div 60$ = SCFM

Per cent isokinetic sampling

$$I = \frac{1.667 \left[(0.00267) \quad V_{lc} \quad + \quad \frac{V_m}{T_m} \left(P_B + \frac{\Delta H}{13.6} \right) \right] T_s}{\theta \, V_s \, P_s \, A_n}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$0.00267 = \frac{\rho H_2O}{M_{H_2O}} \times R \times \frac{lb.}{454 \; gm.}$

θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$C_s = 2.205 \times 10^{-6} \left(\frac{M_n}{Vm_{std}} \right)$

C_s = particulate emission, lb/scf

2.205×10^{-6} = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_S \times Q_s$ = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% EA = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: IP - Wood Fired, #1 Blr Date: 6/19

Material collected (mg) =

Filter Catch = 14.2
Dry Catch =
Acetone Wash = 1.5

TOTAL = 15.7

Gas Volume $Vm_{std} = 0.0334 \left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$

$0.0334 \left(\frac{77.715}{1.021}\right)\left(29.96 + \frac{0.767}{13.6}\right) = \underline{76.089}$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

$0.0474\ (181.1\ ml) = \underline{8.584}$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(8.584)}{(76.089)+(8.584)} = \underline{10.1}\ \%$

Molecular Weight of dry stack gas

MW $MW_D = \%\ CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(10.5 \times 0.44) + (8.7 \times 0.32) + (80.8 \times 0.28) = \underline{30.0}$

Molecular Weight of stack gas

$Mws = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 10.1}{100} \times 30.0\right] + \left[\frac{10.1}{100} \times 18\right] = \underline{28.79}$

PARTICULATE SAMPLING CALCULATIONS

Test: IP - Wood River - #1 Blr. **Date:** 6/19

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times \Delta P\ avg}{P_s \times Mw_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{743 \times 0.717}{29.9 \times 28.79}\right]^{1/2} =$ 57.84 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%M}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(10.1)}{100}\right](57.84)\ (75.14)\ \frac{530}{(743)}\ \frac{(29.9)}{29.92} =$ 10,026,753 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6} \left(\frac{15.7}{75.679}\right) =$ 4.58×10^{-7} lb/scf

$C_E = C_s \times Q_s = (4.58 \times 10^{-7})\quad (10,026,753) =$ 4.59 lb/hr

$C_H = C_E \div H = \left(\frac{4.59}{812.4}\right) =$ 5.65×10^{-3} lb/10^6 Btu

Isokinetic Variations $I = \frac{1.667\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right]T_s}{\theta\ V_s\ P_s\ A_n}$

$$\frac{1.667\left[(0.00267)\quad(181.1) + \frac{76.117}{530}\left(29.86 + \frac{0.784}{13.6}\right)\right](743)}{(126)\quad(57.84)\quad(29.9)\quad(3.406 \times 10^{-4})} = 98.23$$

Excess Air at Sample Point

$\%EA = \frac{100 \times \%O_2}{(0.266 \times \%N_2) - \%O_2}$

$\frac{100\ (8.9)}{(0.266 \times 80.6) - (8.9)} =$ 70.75

PARTICULATE SAMPLING CALCULATIONS

Test: IP Wood River #4 Date: 6/28

Material collected (mg) =

Filter Catch = 65.1
Dry Catch =
Acetone Wash = 41.8

TOTAL = 106.9

Gas Volume $Vm_{std} = 0.0334 \left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$

$0.0334\left(\frac{106.635}{1.021}\right)\left(29.63 + \frac{1.46}{13.6}\right) = \underline{103.734}$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

0.0474 (196.9ml) = 9.333 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(9.333)}{(103.734) + (9.333)} = \underline{8.25}$ %

Molecular Weight of dry stack gas

MW $MW_D = \%CO_2 \times 0.44 + \%O_2 \times 0.32 + \%N_2 \times 0.28$

$(16.4 \times 0.44) + (6.4 \times .32) + (77.2 \times 0.28) = \underline{30.89}$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.25}{100} \times 30.89\right] + \left[\frac{8.25}{100} \times 18\right] = 29.83$

PARTICULATE SAMPLING CALCULATIONS

Inst: IP - Wood River - #4 Blr **Date:** 6/85

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times \Delta P\ avg}{P_s \times M_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{756.9 \times 0.058}{29.66 \times 29.83}\right]^{1/2} =$ 16.37 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%M}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(8.25)}{100}\right](16.37)\ (480.9)\ \frac{530}{(756.9)}\ \frac{(29.66)}{29.92} =$ 18,049,222 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(106.9)}{(103.774)} =$ 2.27×10^{-6} lb/scf

$C_E = C_s \times Q_s = (2.27 \times 10^{-6})\ (18,049,222) =$ 41.01 lb/hr

$C_H = C_E \div H = \frac{(41.01)}{(925.0)} =$ 0.044 lb/10^6 Btu

Isokinetic Variations $I = \frac{1.667\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right]T_s}{\theta\ V_s\ P_s\ A_n}$

$\frac{1.667\left[(0.00267)\ (196.4) + \frac{104.442}{530}\left(29.63 + \frac{1.46}{13.6}\right)\right](756.9)}{(116)\ (16.37)\ (29.66)\ (1.36 \times 10^{-3})} =$ 96.8%

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (6.4)}{(0.266 \times 79.2) - (6.4)} =$ 43.6

PARTICULATE SAMPLING CALCULATIONS

Test: IP Wood River #4 Date: 6/26

Material collected (mg) =

Filter Catch = 17.2
Dry Catch =
Acetone Wash = 51.5

TOTAL = 68.7

Gas Volume $Vm_{std} = 0.0334 \left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$

$0.0334\left(\frac{103.089}{1.021}\right)\left(29.64 + \frac{1.43}{13.6}\right) = \underline{99.241}$ SCF

Volume of water vapor Vw = 0.0474 x Vlc

0.0474 (186 ml) = 8.821 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(8.821)}{(99.241) + (8.821)} = \underline{8.16}$ %

Molecular Weight of dry stack gas

MW $MW_D =$ % CO2 x 0.44 + %O2 x 0.32 + %N2 x 0.28

(14.7 x 0.44) + (5.6 x 0.32) + (79.7 x 0.28) = 30.58

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.16}{100} \times 30.58\right] + \left[\frac{8.16}{100} \times 18\right] = \underline{29.55}$

PARTICULATE SAMPLING CALCULATIONS

Test: IP-Wood River - #4 Blr **Date:** 6/26

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times \Delta P\ avg}{P_s \times Mw_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{763.6 \times 0.057}{29.68 \times 29.88}\right]^{1/2} = \underline{16.38}$ fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%H}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(8.16)}{100}\right](16.38)\quad(480.9)\quad\frac{530}{(763.6)}\ \frac{(29.68)}{29.92} = \underline{17,913,219}$ SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{std}}\right)$

$2.205 \times 10^{-6}\ \frac{(29.1)}{(49.241)} = \underline{1.304 \times 10^{-6}}$ lb/scf

$C_E = C_s \times Q_s = (1.304 \times 10^{-6})\quad(17,913,219) = \underline{23.36}$ lb/hr

$C_H = C_E \div H = \frac{(23.36)}{(828)} = \underline{0.028}$ lb/10^6 Btu

Isokinetic Variations $I = \frac{1.667\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right]T_s}{\theta\ V_s\ P_s\ A_n}$

$\frac{1.667\left[(0.00267)\quad(186.1) + \frac{49.429}{530}\left(29.68 + \frac{(1.43)}{13.6}\right)\right](763.6)}{(126)\quad(16.38)\quad(29.68)\quad(1.36 \times 10^{-3})} = \underline{92.2\%}$

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (5.6)}{(0.266 \times 78.7) - (5.6)} = \underline{36.5\%}$

STOICHIOMETRIC
FLOWRATE CALCULATIONS

Boiler #1

Oil Composition		mols/100#			mols O_2 required
S	0.29%	÷ 32	x 1	=	0.009
C	86.4	÷ 12	x 1	=	7.200
H_2	12.7	÷ 2 = 6.35	x 0.5	=	3.175
N_2	0.2	÷ 28 = 0.007			
O_2	0.2	÷ 32	x -1	=	-0.006
Ash	trace				
Btu	140,000 Btu/gal				

Theoretical O_2 = 10.378

Excess air = 70.7%

excess O_2 = 7.337

O_2 Total = 17.715

$N_2 = 3.76 \times O_2$ = 66.608

Mols Flue Gas = $CO_2 + SO_2 + N_2 + O_2 + N_2$
= 7.200 + 0.009 + 0.007 + 7.337 + 66.608 = 81.161

Flue Gas = 58.54 x 386.7 $\frac{ft^3}{mol}$ = 31385 scf/100#

@61gpm = 61 x 7.171 $\frac{\#}{gal}$ x $\frac{1}{100\#}$ x 22637.4 = 137,288 SCFM

= 8,237,263 SCFH

STOICHIOMETRIC
FLOWRATE CALCULATIONS

Boiler #4

Composition of Coal		Lb-mols/100 lbs Coal		Oxygen Required for Combustion, mols
C	61.43%	5.12	(1)	5.12
H_2	4.38	(2.19)	(2)	(1.09)
S	3.21	0.10	(3)	0.10
O_2	9.67	0.30		-.30
N_2	1.11	0.04	(4)	-
H_2O (moisture)	11.82	(0.66)	(2)	-
Ash	8.55	-		
Chlorides	0.02	-		
	100.19			6.01 Moles oxygen

Average Excess Air: 40% 2.40

Total 8.41

Corresponding Nitrogen 31.77

Assumed reactions:

(1) $C + O_2 \rightarrow CO_2$

(2) Excluded from calculation for dry flue gas

(3) $S + O_2 \rightarrow SO_2$

(4) Oxidation reaction uncertain

Dry flue gases per 100 lbs coal, lb-mols:

CO_2	5.12
SO_2	0.10
O_2	2.40
N_2	0.04
Air (Nitrogen)	31.77
Total	39.43

lb-mol × 386 = SCF

Total 39.43 = 15,220 SCF/100#

@ 43 tons coal/hour = 13,089,200 SCFH

NO_x EMISSION DATA

Date 6/17 & 6/18 Gas Fired

Run No.	1	2	3	4	1	2	3	4
Time	–	–	–	–	1130	1400	1500	1520
µg NO_2	blank	256	276	288	188	182	192	152
T_i = Initial Flask Temp, °F	90	90	90	90	90	90	90	90
T_f = Final Flask Temp, °F	90	90	90	90	90	90	90	90
V_{fc} = Flask Volume, ml.	2047	2038	2031	2018	2047	2038	2019	2024
P_i = Initial Flask Pres, "Hg	3.0							
P_f = Final Flask Pres, "Hg	29.7							
lb/scf NO_2 $\times 10^{-6}$	–	8.7	9.8	10.1	5.8	6.3	6.0	[illegible]
lb/10^6Btu NO_2	–	0.12	0.14	0.14	0.08	0.07	[illegible]	[illegible]

$$V_{sc} = \left(17.71\ \frac{°R}{\text{in. Hg}}\right) (V_{fc}) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5}\ \frac{\text{lb/scf}}{\mu\text{g/ml}} \left(\frac{\mu\text{g } NO_2}{V_{sc}}\right) = \text{lb/scf } NO_2$$

NO_x EMISSION DATA

Date 9/19 Oil Fired

Run No.	1	2	3	4	5	6	7	8
Time	1200	1230	1300	1330	1400	1500	1530	1600
µg NO_2	220	212	196	234	227	214	223	220
T_i = Initial Flask Temp, °F	90							
T_f = Final Flask Temp, °F	90							
V_{fc} = Flask Volume, ml.	2047	2038	2039	2028	2025	2022	2026	2036
P_i = Initial Flask Pres, "Hg	3.0							
P_f = Final Flask Pres, "Hg	29.7							
lb/scf NO_2 $\times 10^{-6}$	7.7	7.5	6.9	8.0	8.1	7.8	7.8	7.7
lb/10^6Btu NO_2	0.12	0.12	0.11	0.13	0.13	0.13	0.13	0.12

$$Vsc = \left(17.71 \frac{°R}{in.\ Hg}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = scf$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{lb/scf}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = lb/scf\ NO_2$$

NO_x EMISSION DATA

Date 6/20 Oil Fired

Run No.	1	2	3	4				
Time	1335	1350	1330	1359				
ug NO_2	173	172	162	173				
T_i = Initial Flask Temp, °F	90	—	—	—				
T_f = Final Flask Temp, °F	90	—	—	—				
V_{fc} = Flask Volume, ml.	2047	2038	2037	2028				
P_i = Initial Flask Pres, "Hg	1.0	—	—	—				
P_f = Final Flask Pres, "Hg	29.8	—	—	—				
lb/scf NO_2 $\times 10^{-6}$	6.1	6.2	5.7	6.0				
lb/10^6Btu NO_2	0.10	0.10	0.09	0.10				

$$Vsc = \left(17.71 \frac{{}^{\circ}R}{\text{in. Hg}}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \ \frac{\text{lb/scf}}{\text{ug/ml}} \left(\frac{\text{ug } NO_2}{Vsc}\right) = \text{lb/scf } NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	6/20		6/20	6/20		
Run No.	1		2	1+2		
V_{mc}-Meter Volume, Ft^3	7.513		7.079	14.592		
Vmstd-Meter Volume, Std. Cond.	7.336		6.912	14.248		
Pb-Barometric Pressure, "Hg	29.84		29.84			
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1		0.1			
V_t-Vol. of Titrant, ml.	0.4		0.4	43.5		
V_{tb}-Vol. of Titrant for Blank, ml.	nil		nil	nil		
Vsoln-Vol. of Solution, ml.	100		100	500		
V_a-Vol. of Aliquot, Titrated, ml.	10		10	50		
lb/scf H_2SO_4 $\times 10^{-7}$	5.89		6.25			
lb/10^6 Btu H_2SO_4	0.01		0.01			
lb-scf SO_2 $\times 10^{-5}$				2.15		
lb/10^6 Btu SO_2				0.35		

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) \; (N) \; \left(\frac{Vsoln}{Va}\right)}{V_{mstd}} = lb/scf$$

N = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) \; (N) \; \left(\frac{Vsoln}{Va}\right)}{V_{mstd}} = lb/scf$$

Hydrocarbon Results

Test: IP Wood River #1 Date: 6/18 Time: 1120

Carbon Monoxide: 1.29 ppm

Methane: 1.81 ppm

Total Hydrocarbons, as CH_4: 1.87 ppm

Test: Wood River #1 Date: 6/18 Time: 1420

Carbon Monoxide: 4.23 ppm

Methane: 0.85 ppm

Total Hydrocarbons, as CH_4: 1.90 ppm

Test: Wood River #1 Date: 6/19 Time: 1200

Carbon Monoxide: 0.272 ppm

Methane: 0.604 ppm

Total Hydrocarbons, as CH_4: 1.837 ppm

Test: Wood River #1 Date: 6/19 Time:

Carbon Monoxide: 0.273 ppm

Methane: 0.634 ppm

Total Hydrocarbons, as CH_4: 3.112 ppm

NO_x EMISSION DATA

Date 6/28

Run No.	1	2	3	4	5	6	9	10
Time	1220	1310	1420	1425	1610	1640	1710	1715
µg NO_2	1190	1500	1160	1120	1180	1120	1160	1420
T_i - Initial Flask Temp, °F	90							
T_f - Final Flask Temp, °F	90							
V_{fc} - Flask Volume, ml.	2047	2019	2039	2028	2018	2021	2041	2056
P_i - Initial Flask Pres, "Hg	2.0							
P_f - Final Flask Pres, "Hg	29.6							
lb/scf NO_2 $\times 10^{-6}$	4.8	6.2	4.1	4.7	4.6	4.2	4.2	5.0
lb/10^6Btu NO_2	0.64	0.76	0.58	0.67	0.60	0.61	0.61	0.71

$$Vsc = \left(17.71 \frac{°R}{in.\ Hg}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = scf$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{lb/scf}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = lb/scf\ NO_2$$

NO_x EMISSION DATA

Date 6/26

Run No.	1	2	3	4	5	6	7	10
Time	1200	1230	1130	1315	1415	1448	1515	1620
ug NO_2	1450	1370	940	1010	1150	1280	1310	1950
T_i - Initial Flask Temp, °F	90							
T_f - Final Flask Temp, °F	86							
V_{fc} - Flask Volume, ml.	2047	2038	2029	2020	2025	2052	2010	2016
P_i - Initial Flask Pres, "Hg	3.0							
P_f - Final Flask Pres, "Hg	29.6							
lb/scf NO_2 $\times 10^{-5}$	4.4	4.8	3.3	4.3	4.1	4.4	4.6	5.1
lb/10^6Btu NO_2	0.62	0.69	0.47	0.61	0.58	0.62	0.65	0.72

$$Vsc = \left(17.71 \frac{°R}{in.\ Hg}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = scf$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5}\ \frac{lb/scf}{ug/ml} \left(\frac{ug\ NO_2}{Vsc}\right) = lb/scf\ NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	6/26	6/26		6/27	6/27	6/27
Run No.	1	1		1	2	1+2
V_{mc}-Meter Volume, Ft^3	7.695	7.695		7.482	7.301	
Vmstd-Meter Volume, Std. Cond.	7.517	7.517		7.106	7.060	14.166
P_B-Barometric Pressure, "Hg	29.62			29.25	29.[illegible]	
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1			0.1		
V_t-Vol. of Titrant, ml.	5.9	17.4		5.9	5.6	30.1
V_{tb}-Vol. of Titrant for Blank, ml.	nil	nil		nil	nil	nil
Vsoln-Vol. of Solution, ml.	100	250		100	100	250
V_a-Vol. of Aliquot, Titrated, ml.	25	10		25	25	10
lb/scf H_2SO_4 $\times 10^{-6}$	3.4			3.5	3.4	
lb/10^6 Btu H_2SO_4	0.05			0.05	0.05	
lb-scf SO_2 $\times 10^{-4}$		4.07				3.72
lb/10^6 Btu SO_2		5.77				5.27

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4} \frac{lb-l}{g-ml}\right) (V_t - V_{tb}) \; (\underline{N}) \; \left(\frac{V_{soln}}{Va}\right)}{V_{mstd}} = lb/scf$$

$\underline{N}$ = 0.01 Normal
Barium
Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{lb-l}{g-ml}\right) (V_t - V_{tb}) \; (\underline{N}) \; \left(\frac{V_{soln}}{Va}\right)}{V_{mstd}} = lb/scf$$

HYDROCARBON ANALYSIS

TEST: IP Wood River #4 DATE: 6/26 TIME: 1400

COMPOUND	CONCENTRATION (ppm)
Ethane	0.074
Propane	0.043
1 - Butene	0.015
n - Butane	0.018
Iso - Pentane	0.018
cis, 2 - Pentene	0.016
1 - Hexene	0.046
n - Hexane	0.117
3,3 dimethyl, 1 - Pentene	0.029
2,4 dimethyl Pentane + Benzene	0.068
1 - Heptene	0.040
n - Heptane	0.016
Toluene	0.065
Ethyl Benzene	0.113
meta-, para-, xylene	0.394
orthoxylene	0.087
C_3's	0.043
C_4's	0.052
C_5's	0.143
C_6's	0.308
C_7's	0.185
C_8's	0.622

APPENDIX B
FIELD DATA

SUPPLEMENTARY PROCESS & EMISSION DATA FOR POWER PLANTS

Test number	6/17	6/18	6/19	6/20*
Net Unit Load - MW		43		
Boiler Heat Rate - BTU/KW hr.		13,848		
Boiler Heat Input - 10^6 BTU/hr.	592.1	597.4	512.4	512.4
Emission Level - lb./10^6 BTU				
Particulates				
SO_2				
NO_x				
Fuel Heating Value - BTU/lb.	1030 Btu/CF	1030 Btu/CF	19820	
Fuel Burning Rate During Test - lb./hr.	575 10^3CF/hr	580 10^3CF/hr	61 GPM	
Fuel Ash Content - %				
Additive Rate - lb/hr.				

*Assumed same as 6/19

ORSAT FIELD DATA

Location ILL POWER - BOILER 1   Comments:

Date

Time

Operator

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
6.17	1.8 %	7.2 %	0.0 %
6.18	7.2 %	8.4 %	0.0 %

6.18 Mw dry = .072 (44) + .084 (32) + .844 (28)
3.2 2.7 23.6 = 29.5 Mw(dry)

@ 16.5 % H_2O

Mw wet = .165 (18) + .835 (.072)(44) + .835(.084)(32) + .835(.844) 28
2.97 2.65 2.24 19.73 = 27.
Mw

ORSAT FIELD DATA

Location ILL. POWER CO. ALTON ILL.

Date

Time

Operator

Comments: No. 1 BOILER

TEAM
LITTMAN
GRISCOM
KLEIN

DATE	Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
6.19.75	1120 hrs.	8.6	17.6/9.0	17.6
	1600 hrs.	12.0	20.8/8.8	20.8
6.20.75	1130 hrs.	15.0	23.2/8.2	23.2
	1300 hrs.	11.4 *	16.4/5.0	16.4
	avg. 6/19	10.3	8.9	0.0

* Sampled at economizer .. plant sample point on 4th floor of boiler house

6.19 Mw dry = .103 (44) + .089 (32) + .808 (28) = 30.0
4.53 2.85 22.62

Mw wet = .899 (30) + .101 (18) = 26.97 + 1.82 = 28.79

6.20 Mw dry = .15 (44) + .082 (32) + .768 (28) = 30.72
6.6 2.62 21.50

Plant IP Wood River

Run No. 1

Location #1 Boiler

Date 6-18

Operator

Sample Box No.

Meter Box No.

Meter ΔH@ 1.822

C Factor

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

#5 Filter

Ambient Temp °F 85-90

Bar. Press. "Hg

Assumed Moisture % 15

Heater Box Setting °F (4)

Probe Tip Dia., In. 3/8 in

Probe Length 10 ft

Probe Heater Setting 7

Avg. ΔP ____ Avg. ΔH ____

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-6	12:08	126.445	0.45	0.6	0.6	185	80	5.5	305	162		290
1-5	12:11	128.150	0.75	1.0	1.0	220	70	8.5	300	150		290
1-4	12:14	130.24	0.7	1.2	1.2	220	65	11.0	305	175		290
1-3	12:17	132.90	0.9	1.2	1.2	220	65	11.0	310	180		290
1-2	12:20	135.14	0.75	1.0	1.0	245	65	9.5	315	180		290
1-1	12:23	137	0.15	.2	.2	250	70		325	175		285
	12:26											
2-1	1:58	138.9	.35	0.5	0.5	205	90	4.5	370	135		290
2-2	2:01	140.3	0.9	1.3	1.3	280	70	12.5	360	170		290
2-3	2:04	142	1.1	1.5	1.5	280	70		350	170		290
2-4	2:07	145.2	1.2	1.65	1.5	280	75	15	340	175		290
2-5	2:10	147.8	1.1	1.5	1.5	285	80	15	335	180		300
2-6	2:13	150.45	0.9	1.3	1.3	280	85	12.5	335	180		300
	2:16	152.720										

Run No. 1

Point	Clock Time	Dry Gas Meter, CF	Pitot In. H_2O ΔP	Orifice ΔH In. H_2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
3-1	2:58	152.90	.3	0.4	.4	110	100	4	315			250
3-2	3:01	154.4	.5	1.2	1.2	325	85	11.5	325	150		280
3-3	3:04	156.6	1.1	1.5	1.5	355	85	15	325	170		295
3-4	3:07	158.[illegible]	1.1	1.5	1.5	355	95	15	320	175		300
3-5	3:10	[illegible].6	1.1	1.5	1.5	360	100	15	320	180		300
3-6	3:13	162.4	0.9	1.2	1.2	360	105	12	320	180		300
—	3:16	[illegible].92										

Comments: Filter No. 5

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant: IP Wood River
Run No. 2
Location: #1 Blr
Date: 6-19
Operator:
Sample Box No.
Meter Box No.
Meter ΔH@ 1.622
C Factor

Ambient Temp °F: 90°F
Bar. Press. "Hg: 29.86
Assumed Moisture %: 16.9
Heater Box Setting °F: 325 ±
Probe Tip Dia., In.: 1/4 in
Probe Length: 10 ft.
Probe Heater Setting: 4 280°-300°
Avg. ΔP ____ Avg. ΔH ____

Point	Clock	Dry Gas Meter, CF	Pitot in H₂O ΔP	Orifice ΔH in H₂O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	11:18	167.400	.6	.85	.85	185	70	16.5	320	295	0.5	280
1-2	11:21		.78	1.3	1.0	210	65	17.5	320	300		285
1-3	11:24	170.05	.98	1.5	0.9	220	65	17.5	340	315		285
1-4	11:27	173.63	.96	1.5	0.9							
1-5	11:30	175.30	.88	1.4	0.9	250	65	17.5	350	305		285
1-6	11:33	177.40	.6	.7	.7	260	70	13.5	350	305		280
	11:36	179.255										
2-1	12:35	181.420	0.4	0.55	.55	225	75	9	340	305		270
2-2	12:38	182.000	1.00	1.3	.95	255	70	17.5	350	290		270
2-3	12:41	185.10	.85	1.7	.95	265	70	17.5	355	305		270
2-4	12:44	187.20	.88	1.6	.95	270	70	17.5	355	300		270
2-5	12:47	189.3	.85	1.7	.95	275	75	17.5	355	295		260
2-6	12:50	190.4	.75	1.65	.95	280	75	17	360	300		260
	12:53	193.16										

Meter Cal ±05%

[illegible]

Run #2

Point	Clock Time	Dry Gas Meter, CF	Pitot In. H2O ΔP	Orifice ΔH In. H2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
2-1	1:40	192.262	.36	.34	.34	220	80	6.5	355	290		270
2-2	1:43	194.6	1.2	1.4	1.2	245	70	17.5	360	295		270
2-3	1:46	196.6	.98	1.6	1.6	270	65	17.5	365	315		255
2-4	1:49	198.6	.98	1.6	1.6	275	65	17.5	360	325		280
2-5	1:52	200.75	.98	1.6	1.5	285	70	17.5	365	330		265
2-6	1:55	202.7	.95	1.3	1.8	290	70	17.5	365	330		262
end	1:58	204.845										
4-1	2:58	204.845	0.2	.38	.3	265	80	5.5	330	270		280
4-2	3:00	206.0	0.3	1.1	1.0	240	65	17	330	270		285
4-3	3:04	207.15	0.3	1.1	1.0	255	65	17	335	280		290
4-4	3:07	208.8	0.3	1.1	1.0	265	65	17	340	290		290
4-5	3:10	210.9	0.30	1.2	1.0	270	65	17	345	300		280
4-6	3:13	214.0	0.35	1.2	1.0	265	70	17	350	305		290
end	3:16	216.160										
5-1	3:35	216.160	0.1	0.14	0.6	195	90	3.5	340	320		290
5-2	3:37	216.95	0.6	0.9	0.5	250	80	14.5	345	275		285
5-3	3:40	218.57	0.5	.08	0.7	270	75	13	350	305		300
5-4	4:03	220.7	.15	0.9	0.7	275	75	16	350	300		290
5-5	4:06	222.25	.8	1.1	0.9	280	80	17	355	300		285
5-6	4:09	224.8	.8	1.1	0.9	285	80		365	320		285
end	4:12	226.540										

Comments

$\bar{T}_s$ ave =

Point	Clock Time	Dry Gas Meter, CF	Pitot In. H₂O Δ P	Orifice ΔH In. H₂O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
6-1	4:55	226.840	0.15	0.3	0.3	195	90	4.5	365	215		295
6-2	4:58	227.185	0.6	0.8	0.8	255	80	13.5	350	280		300
6-3	5:01	228.7	.45	.65	.65							
6-4	5:04	229.45	0.6	.8	0.8	275	75	14.5	355	290		295
6-5	5:07	230.45	0.7	1.0	.95							
6-6	5:10	236.5	0.6	0.8	0.8	280	75	14	355	280		295
end	5:13	237.455										
7-1	5:49	237.455	0.15	0.3	0.3			4.5				
7-2	5:52	238.40	0.4	0.55	0.55	255	85	10	345	285		300
7-3	5:55	240.1	0.4	0.55	0.55							
7-4	5:58	240.78	0.5	0.67	0.67	275	80	12	360	340		295
7-5	6:01	240.55	0.55	0.7	0.7							
7-6	6:04	241.35	0.35	0.5	0.5	285	85	10	365	320		295
end	6:07	242.490										
8-1												
8-2	Bottom Hole Filled Deposits											
8-3												
8-4												
8-5												
8-6												
end												

Comments: Vs = 85.48(.84)(√ΔP) [illegible]

[illegible]

24

PARTICULATE CLEANUP SHEET

Date: 6/19/78
Plant: IP - Wood River
Run Number: 2
Location Of Sample Port: #1 Boiler Duct
Operator: ____________
Barometric Pressure: 29.86 in. Hg.
Sample Box No. ____________
Ambient Temperature 90 °F

Impinger H2O

Volume After Sampling 361 ml
Impinger Prefilled With 200 ml
Volume Collected 161 ml

Silica Gel

Weight After 378.2 g
Weight Before 358.1 g
Moisture Weight 20.1 g Moisture Total 181.1 g

Dry Probe and Cyclone Catch:
Container No. ____________
Extra No. ________ Weight Results ________ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No. ____________
Extra No. ________ Weight Results 0.0016 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
4			

Filter Particulate Weight 0.0111 g

Total Particulate Weight 0.0127 g

% Moisture By Volume $V_{m_{std}} = 0.0334\left(\frac{77.715}{1.031}\right)\left(29.86 + \frac{0.784}{13.6}\right) = 76.021$ cu. ft.

$V_{w_{std}} = 0.0474\,(181.1) = 8.584$ cu. ft.

$\%H_2O = \frac{8.584}{76.021 + 8.584} = .101$ or 10.1 % moisture

OXIDES OF NITROGEN FIELD DATA

Date 6/17 + 6/18

Plant IP-Wood River - Blr #1

Sample Collected By O. Klein

Run No.

Power Stat Setting

Field Data	6/17				6/18			
Clock time	blank	"	"	"	1130	1200	1400	1430
Flask number	1	2	3	4	1	2	3	4
Volume of flask less correction (ml)	2047	2038	2039	2048	2047	2038	2039	2048
Pressure before sampling in. Hg.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Pressure after sampling, in. Hg.	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Flask temperature, °F	90	90	90	90	90	90	90	90

OXIDES OF NITROGEN FIELD DATA

Date 6/19

Plant I P - Wood River - BLR #1

Sample Collected By O. Klein

Run No.

Power Stat Setting

Field Data

Clock Time	1200	1230	1300	1330	1400	1500	1530	1600
Flask number	1	2	3	4	5	6	7	8
Volume of flask less correction (ml)	2047	2018	2039	2026	2048	2034	2037	[illegible]
Pressure before sampling in. Hg.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	[illegible]
Pressure after sampling, in. Hg.	29.7	29.7	29.7	29.7	29.7	29.7	29.7	29.7
Flask temperature, °F	90	90	90	90	90	90	90	90

OXIDES OF NITROGEN FIELD DATA

Date 6/20

Plant IP : Wood River - Blr #1

Sample Collected By O. Klein

Run No.

Power Stat Setting

Field Data

Clock Time	1115	1350	1310	1355				
Flask number	1	2	3	4				
Volume of flask less correction (ml)	2047	2038	2039	2028				
Pressure before sampling in. Hg.	3.0	3.0	3.0	3.0				
Pressure after sampling, in. Hg.	29.7	29.7	29.7	29.7				
Flask temperature, °F	90	90	90	90				

GAS SAMPLING FIELD DATA

Material Sampled For Sulfuric Mist & SO2

Date 6-20-78

Plant Wood River   Location #1 Boiler

Bar. Pressure 29.84 "Hg   Comments:

Ambient Temp 85° °F

Run No 1

Power Stat Setting Probe 4 @ 315°F

Filter Used: Yes ______ No X Shell method

Operator ______

Clock Time	Meter (Ft.³)	Pitot In. H2O ΔP	Orifice in H2O ΔH	Temperatures Stack	Probe	Coil	Impinger In	Out
12:02	253.747	0.7	0.1 in H2O	290°F	310°F	65°F		
12:07	254.000	0.7	0.1		315°F	73°F	145°F	55°F
12:12	256.27	0.7	0.1		310°F	73°F	135°F	55°F
12:17	257.55	0.7	0.1		305°F		130°F	52°F
12:22	258.82	0.7	0.1		315°F	73°F	125°F	52°F
12:27	260.10	0.7	0.1 (In Vac)		315°F		125°F	52°F
12:32	261.260	0.7	off		315°F	72°F	120°F	55°F

Comments:

GAS SAMPLING FIELD DATA

Material Sampled For Sulfuric Mist & SO_2

Date 6.20

Plant Wood River   Location #1 Blr.

Bar. Pressure 29.84 "Hg   Comments:

Ambient Temp 90 °F

Run No 2

Power Stat Setting ________

Filter Used: Yes ________ No ____

Operator ________________________________

So 2 Impingers not changed

Clock Time	Meter (Ft.³)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures				
				Stack	Probe	Coil	Impinger In	Impinger Out
1:07	261.260	0.7	0.1		335°F	76°F	170°F	85°F
1:12	262.475	0.7	0.1		345°F		170°F	90°F
1:17	263.68	0.7	0.1(in Hg)		335°F	80°F	155°F	90°F
1:22	264.875	0.7	0.1		325°F	78°F	145°F	90°F
1:27	266.02	0.7	0.1		325°F	78°F	135°F	88°F
1:32	267.18	0.7	0.1		325°F	77°F	135°F	90°F
1:37	268.337		off					

Comments:

SUPPLEMENTARY PROCESS & EMISSION DATA FOR POWER PLANTS

Test number	6/25	6/26	6/27	
Net Unit Load - MW	100	100	100	
Boiler Heat Rate - BTU/KW hr.				
Boiler Heat Input - 10^6 BTU/hr.	925.0	925.0	925.0	
Emission Level - lb./10^6 BTU				
Particulates				
SO_2				
NO_x				
Fuel Heating Value - BTU/lb.	10756	10756	10756	
Fuel Burning Rate During Test - lb./hr.	86000	86000	86000	
Fuel Ash Content - %				
Additive Rate - lb/hr.				

ORSAT FIELD DATA

Location ILL Power Co. Alton, Ill.

Date

Time

Operator

Comments:

No. 4 Boiler

Team
Griscom
Klein
Norris

DATE	Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
6.25.75	1340 hrs	16.4	22.8/6.4	22.8
6.26.75	1245 hrs.	13.2	19.0/5.8	19.0
	1535 hrs.	16.2	21.6/5.4	21.6
6.27.75	1030 hrs.	15.3	20.8/5.5	20.8

6.25. $MW_D = .164(44) + .064(32) + .772(28) = 30.87$

$MW_{wet} = .9175(30.87) + .0825(18) = 28.34 + 1.49 = 29.83$

6.26 $MW_D = .147(44) + .056(32) + .797(28) = 30.58$

6.47 1.79 22.32

$MW_{wet} = .9184(30.58) + .0816(18) = 28.08 \quad 1.47 \quad 29.55$

6.27 $MW_D = .153(44) + .055(32) + .792(28) = 30.67$

6.73 1.76 22.18

Plant Wood River

Run No. 1

Location #4 Stack

Date 6-25-75

Operator

Sample Box No.

Meter Box No.

Meter ΔH@ 1.632

C Factor 0.55

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

#3 Filter

Static press 0.4 in H2O

Ambient Temp °F 85

Bar. Press. "Hg 29.63

Assumed Moisture % 8

Heater Box Setting °F @ 4 320°F

Probe Tip Dia., In. 1/2

Probe Length 10 ft

Probe Heater Setting

Avg. ΔP .05 Avg. ΔH

	Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
					Desired	Actual	Inlet	Outlet					
[illegible]	1	7am	269.350	0.030	0.5	0.5	325	60	2.5	330	270		170
[illegible]	2		273.0	0.05	1.25	1.25	240	60	6.0	335	320		260
[illegible]	3		278.0	0.055	1.4	1.4	270	65	6.0	350	335		310
[illegible]	4		285.1	0.055	1.4	1.4	275	65	6.0	345	395		320
[illegible]	5		291.0	0.06	1.5	1.5							
	6		297.4	0.065	1.6	1.6	270	65		315	365		320
[illegible]	7		304.0	0.065	1.6	1.6	270	65	6.5	365	335		320
[illegible]	8		310.0	0.06	1.5	1.5	265	65	6.5	300	330		320
[illegible]	9		316.0	0.06	1.5	1.5	265	65	6.5	310	340		320
[illegible]		8:45	321.965										

Run #1

Point	Clock Time	Dry Gas Meter CF	Pitot In. H2O ΔP	Orifice ΔH In. H2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
18	4:35	321.965	0.04	1.8	1.8	265	65	4.0	360	265		318
17		326.6	0.06	1.5	1.5	280	63	7.0	370	365		310
16		333	0.07	1.75	1.75	285	70	8.0	380	335		310
15		339.4	0.07	1.75	1.75	290	70	8.5	355	325		320
14		345.7	0.07	1.75	1.75	285	72		345	315		320
13		352	0.06	1.5	1.5	275	75	7.0	360	310		320
12		358	0.06	1.5	1.5	265	80	7.0	355(?)	300(?)		320
11		364	0.07	1.75	1.75	275	75	8.0	350	365(?)		320
10		370	0.06	1.5	1.5	275	70	7.0	350	365(?)		
		375.965										

Comments:

PARTICULATE CLEANUP SHEET

Date: 6/25
Plant: IP Ween River
Run Number: 1
Location Of Sample Port: #4 Boiler Stack
Operator:
Barometric Pressure: 29.64
Sample Box No.
Ambient Temperature 85

Impinger H2O
Volume After Sampling 368.5 ml
Impinger Prefilled With 200 ml
Volume Collected 168.5 ml

Silica Gel
Weight After 516.5 g
Weight Before 488.1 g
Moisture Weight 28.4 g Moisture Total 196.9 g

Dry Probe and Cyclone Catch:
Container No.
Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:
Container No.
Extra No. Weight Results 0.041 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
3			

Filter Particulate Weight 0.0651 g

Total Particulate Weight 0.1061 g

% Moisture By Volume

Plant Wood River

Run No. 2

Location Blr #4

Date 6-26

Operator

Sample Box No.

Meter Box No.

Meter ΔH@ 1.622

C Factor .55

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 90°F

Bar. Press. "Hg 29.62

Assumed Moisture % 8%

Heater Box Setting °F 4

Probe Tip Dia., In. 1/2

Probe Length 10 ft

Probe Heater Setting

Avg. ΔP 0.06 Avg. ΔH 1.5

2 Filter
Static press. .4 in H_2O

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
18	11:45	375.965	0.03	0.75	0.75	230	65	4	330	240		175
17		380	.05	1.25	1.25	245	63	6	320	290		260
16		385.8	.07	1.75	1.75	265	65	9	330	325		320
15		392	.07	1.75	1.75	280	69	9	340(15)	320 (6)		320
14		398	.07	1.75	1.75	290	69	9	345	320		320
13		405.7	.07	1.75	1.75	285	69	9	350	320		320
12		411	.05	1.25	1.25	285	70	6	350(4)	325(5.5)		320
11		416.5	.05	1.25	1.25	285	70	6	325	320		320
10		422	.05	1.25	1.25	290	74	6	355	320		320
	12:48	427.650										

Run #2

Point	Clock Time	Dry Gas Meter, CF	Pitot In. H₂O ΔP	Orifice ΔH In. H₂O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
9		427.050	0.06	1.5	1.5	185	75	8.5	315(7)	170		226
8		433	0.06	1.5	1.5	260	71	8.5	340	315(7)		225
7		438.7	0.06	1.5	1.5	280	70	8.5	300(4)	355(5)		220
6		445.5	0.06	1.5	1.5	281	71	8.5	360	325		220
5		451.5	0.06	1.5	1.5	265	75	9.0	360	355(7)		220
4		456.0	0.08	1.5	1.5	250	70	9.0	365(5)	285(6)		220
3		462.0	0.06	1.5	1.5	265	80	9.0	360	330		220
2		468.0	0.06	1.5	1.5	260	85	9.0	345	365		220
1		473.5	0.04	1.0	1.0	255	85	7.0	325	310		225
		478.053										

start
0823.01

[illegible] leak at joint at end of probe

[illegible] when box is far out [illegible] nozzle not vertical

PARTICULATE CLEANUP SHEET

Date: 6/26

Plant: IP Wood River

Run Number: # 2

Location Of Sample Port: #4 Boiler Stack

Operator:

Barometric Pressure: 29.62

Sample Box No.

Ambient Temperature 90

Impinger H2O

Volume After Sampling 358 ml

Impinger Prefilled With 200 ml

Volume Collected 158 ml

Silica Gel

Weight After 528.1 g

Weight Before 500.0 g

Moisture Weight 28.1 g Moisture Total 186.1 g

Dry Probe and Cyclone Catch:

Container No.

Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No.

Extra No. Weight Results 0.0215 g

Filter Papers and Dry Filter Particulate

Filter No	Container No.	Filter No.	Container No.
2			

Filter Particulate
Weight 0.0372 g

Total Particulate
Weight 0.0587 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 6/25

Plant IP WOOD RIVER   BOILER #1

Sample Collected By D. KLEIN

Run No.

Power Stat Setting

Field Data

Clock Time	1220	1310	1420	1425	1610	[illegible]	[illegible]	[illegible]
Flask number	1	2	3	4	5	6	7	10
Volume of flask less correction (ml)	2047	2038	2034	2048	2025	2054	2054	2057
Pressure before sampling in. Hg.	3.0	- - -						
Pressure after sampling, in. Hg.	29.6	-						
Flask temperature, °F	70	-						

OXIDES OF NITROGEN FIELD DATA

Date 6/26

Plant IP Wood River Boiler No. 4

Sample Collected By O. Klein

Run No.

Power Stat Setting

Field Data

Clock Time	1200	1230	1330	1335	1415	1445	1515	1540
Flask number	1	2	3	4	5	6	9	10
Volume of flask less correction (ml)	2047	2038	2031	2046	2025	2034	2054	2057
Pressure before sampling in. Hg.	1.0							
Pressure after sampling, in. Hg.	29.6							
Flask temperature, °F	90							

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 6.26

Plant Wood River   Location #4 B/c

Bar. Pressure 2962 "Hg   Comments:

Ambient Temp 80 °F

Run No 1   Traverse Point #5

Power Stat Setting

Filter Used: Yes   No   Shell Method

Operator

8 4 AM

Clock Time	Meter (Ft.³)	Pitot in. H2O ΔP	Orifice in H2O ΔH	Temperatures				
				Stack	Probe	Coil	Impinger	
							In	Out
0	478.045	0.05	0.1	325				
5	479.5	0.05	0.1	325	280	83	170	80
10	481	0.05	0.1	325	285	82.5	150	82
15	482	0.05	0.1	325	305	81	135	83
20	483.2	0.05	0.1	325	310	79	130	83
25	484.4	0.05	0.1	325	300	77.5	120	85
30	485.740							

Comments:

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 6.27

Plant Wood River Location #4

Bar. Pressure 28.547 "Hg Comments:

Ambient Temp 85 °F

Run No 1 Traverse Point #5

Power Stat Setting

Filter Used: Yes No

Operator

	Clock Time	Meter (Ft.^{3})	Pitot in H2O ΔP	Orifice in H2O ΔH	Temperatures				
					Stack	Probe	Coil	Impinger In	Impinger Out
10:55	0	485.748	0.055	0.1	320	280	73		
	5	486.5	0.055	0.1	320	293	73	155	70
	10	488	0.055	0.1	320	315(2)	78	135	72
	15	489.5	0.055	0.1	320	300(2)	78	130	72
	20	490.8	0.055	0.1	320	300	77	125	72
	25	492	0.055	0.1	320	310	76	125	72
	30	493.200							

Comments:

1. Moisture condenses by the impinger inlet Thermowell from ambient cooling
2. Probe setting has to be at 9 to keep temp up [illegible] for the glass probe

GAS SAMPLING FIELD DATA

Material Sampled For SO2 & SO3

Date 6-27

Plant Wood River Location #4

Bar. Pressure 29.35 "Hg Comments:

Ambient Temp 85 °F

Run No 2 Traverse Point #5

Power Stat Setting

Filter Used: Yes No

Operator

	Clock Time	Meter (Ft.³)	Pitot In. H2O ΔP	Orifice In H2O ΔH	Temperatures				
					Stack	Probe	Coil °C	Impinger In	Impinger Out
11:50	0	473.200	0.055	0.1	325	318	74°C	160°ᶠ	85 °F
	5	474.4	0.055	0.1	325	320	83.5	130°	80 °F
	10	475.7	0.055	0.1	325	320	84°	142°	78 °F
	15								
	20	478.1	0.055	0.1	325	325	81°C	132°	75°
	25	479.3	0.055	0.1	330	330(?)	80 °C	130°	80 °F
	30	480.301							

Comments:

Anderson-Particle Size

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Wood River

Run No. 1

Location #4

Date 6-27

Operator

Sample Box No.

Meter Box No.

Meter ΔH@ 1.022

C Factor

Ambient Temp °F 90

Bar. Press. "Hg

Assumed Moisture % 8

Heater Box Setting °F

Probe Tip Dia., In.

Probe Length

Probe Heater Setting

Avg. ΔP Avg. ΔH

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					assumed
5	1:05	500.501	0.055	1.4	1.4	115	75	6	165			325
	1:15		assumed	1.4	1.4	180	70	6	285			
	1:25			1.4	1.4	195	70	6	290			
	1:35			1.4	1.4	200	70	6	270			
	1:45	530.18		1.4	1.4	200	70	6	275			
	1:55	535.35		1.4	1.4	205	72	6	275			
	2:05	545.850	off									

Andersen - Particle Size

Plant Wood River

Run No. #2

Location Blr #4

Date 6-27

Operator

Sample Box No.

Meter Box No.

Meter ΔH@ [illegible]

C Factor

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F [illegible]

Bar. Press. "Hg

Assumed Moisture % 2

Heater Box Setting °F

Probe Tip Dia., In.

Probe Length

Probe Heater Setting

Avg. ΔP ____ Avg. ΔH ____

Point	Clock	Dry Gas Meter, CF	Pitot in H₂O ΔP	Orifice ΔH in H₂O		Impinger °F Temp.		Pump Vacuum In. Hg Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
5	2:18	545.650	.0055	1.4	1.4	310	82		365			325°
	2:28	553.45	[illegible]	1.4	1.4	335	79		300			
	2:38	562		1.4	1.4	385	82		300			
	2:48	-		1.4	1.4	-	-		-			
	2:58	576		1.4	1.4	345	85		365			
	3:08	584		1.4	1.4	365	86		335			
	3:18	591.671										

SOURCE TEST REPORT
HIGHLAND POWER & LIGHT
HIGHLAND, ILLINOIS
BOILER NO. 3
JULY, 1975

Tested by: Rockwell International
R.W. Griscom
D.C. Klein
F.E. Littman

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1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report details the results obtained on boiler No. 3 at the Highland Power and Light Co. in Highland, Illinois.

The stack testing included the following pollutants: SO_2, particulates, NO_x, and H_2SO_4. Orsat analysis for CO_2, CO, and O_2 were also performed. Detailed results are included in this report. Although these tests were not conducted to ascertain compliance with Illinois standards, it is of interest that the particulate emissions are within limits while the SO_2 emissions are not.

We acknowledge and appreciate the excellent cooperation we obtained from the officials of the power company and the City of Highland.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the Highland Power and Light Co. in Highland, Illinois. Testing was performed on boiler No. 3 during the week of 14 July 1975.

Boiler No. 3 is a coal fired, 75,000 pounds per hour steam generating unit. There are no emission controls on this unit. This boiler was sampled for total particulates, particle size, nitrogen oxides, sulfur dioxide, sulfuric acid mist, carbon dioxide, and oxygen.

3.0 PROCESS DESCRIPTION

Boiler No. 3 was built by Union Iron Works and installed in 1959. It is equipped with a traveling grate stoker which is gravity fed. The economizer has not been used for 10 years. The boiler was originally rated at 75,000 pounds per hour steam, however, present operating capacity is approximately 60,000 pounds per hour. Steam pressure is maintained at approximately 610 psi. Boiler No. 3 is an induced draft unit and has no stack emission controls. The stack is of steel construction, 90 feet tall and 5 feet inside diameter.

4.0 SOURCE TEST DESCRIPTION

Boiler No. 3 was tested in the stack, approximately 35 feet above the ground. The City of Highland provided the use of a "cherry picker" for the period of testing. The testing arrangement is illustrated in Figure 1, 2 and 3.

FIGURE 1

POSITIONING OF UNI-STRUTS TO CARRY THE EPA EQUIPMENT

FIGURE 2

ANALYSIS AND PROBE ADJUSTMENT BY OPERATOR IN CHERRY PICKER BUCKET

FIGURE 3

DETAIL SHOWING UNI-STRUTS AT 90 DEGREE PLACEMENT ON STACK.
OPERATOR ADJUSTS PITOT POSITION.

The No. 3 stack is 5.0 feet inside diameter and approximately 90 feet tall. This sampling point is approximately 5 diameters from the flue gas inlet. In accordance with the EPA Standard Method 1, fourteen sampling points were chosen on each of two perpendicular diameters. Two, 3 inch couplings were installed on the stack for use as sampling ports.

5.0 PROCESS OPERATION

Boiler No. 3 was tested 14 July to 16 July. During this testing period, the load on the boiler remained fairly constant since this boiler drives a turbine which provides the baseline electrical generation for the plant. Generator output was generally between 4000 and 4300 KW. There was no visible change in emissions during testing. Ashes were pulled almost every hour. During these periods visible emissions didn't change, but the flow rate in the stack increased.

6.5 DISCUSSION

A problem exists about the use of EPA Standard Method 2, Volumetric Flow Rate Determination. On boiler No. 3 the flow rate determined by method 2 is 23101.2 SCFM compared to a flow rate determined stoichiometrically from the fuel rate and fuel composition of 15182 SCFM. At this sampling point this should have been a good check of method 2, since it was a reasonable distance downstream, 5 diameters, and two complete, perpendicular traverses were made.

The flow rate determined stoichiometrically compares very well with the expected flow as seen by a comparison of sulfur dioxide emissions using both flow rates. Using the published emission factor of 38S, which allows for a 95% conversion of sulfur in the coal to sulfur dioxide emission, the emissions would be 413.87 lb/hr. With the flow rate using method 2 the emissions would be 658.4 lb/hr, which is definitely too great. With the stoichiometric flow rate the emissions would be 432.6 lb/hr, which is a reasonable result. For this reason the emission determined using the stoichiometric flow rate are reasoned to be the correct results.

To determine the amount of coal consumed, the generator output and a ratio of kw to pounds of coal were used to calculate coal consumption. The ratio used was based on operating records for the previous month. Using the current ratio of 1.6, the average fuel consumption for 15 July was 6702.4 lb/hr.

During testing for particle size, the first run was with the Andersen impactor in the stack while the other two were run with the impactor in the oven. For this test, a problem existed which forced the use of an unheated probe. With the impactor in the stack this is no problem, however with the impactor in the oven there was probably some condensation in the probe which increases the weight of particulates.

7.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods.

Gas flow rates were calculated using the observed gas temperature, molecular weight, pressure and velocity, and the flow area. The gas velocity was calculated from gas velocity head measurements made with an S-type pitot tube and a magnehelic pressure gauge, using standard method 2.

Moisture contents were determined by passing a measured amount of gas through chilled impingers containing a known volume of deionized water, measuring the increase in volume of the impingers liquid and the increase in weight of silica gel used to finally dry the gas, and calculating the amount of water vapor in the sample from this increase and the measured amount of gas.

The stack gas concentrations of carbon dioxide, oxygen, carbon monoxide, and nitrogen by difference were measured with a standard Orsat apparatus. These concentrations and the moisture content were used to determine molecular weight of the stack gas.

7.1 PARTICULATE MATTER

Standard method 5 was used for determining particulate emissions with the exception that the probe and oven were operated at 300-350°F. Measured stack gas samples were taken under isokinetic conditions. The samples were passed through a cyclone, fiberglass filter, impingers, pump, a meter and an orifice as shown in Figure 4.

The total particulate matter collected in each test was the sum of the filter catch plus material collected ahead of the filter in the sampling train. The amount of filter catch is determined by the difference in the weight of the filter before and after the test, after dessicating. The particulate matter from other portions of the train was determined by rinsing the probe, cyclone and all glassware ahead of the filter with acetone, evaporating to dryness and weighing.

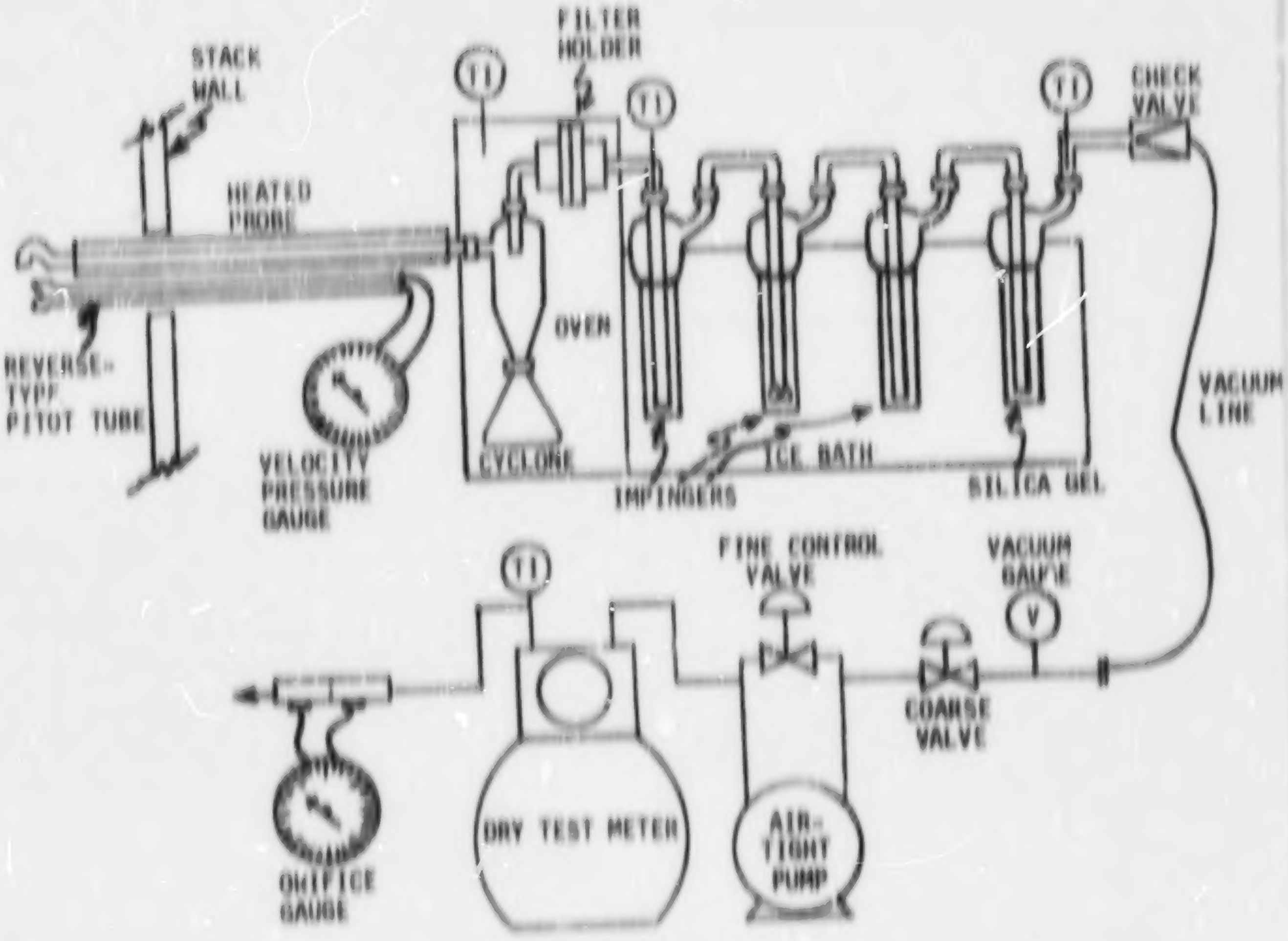
STACK WALL
FILTER HOLDER
TI
TI
TI
CHECK VALVE
HEATED PROBE
OVEN
REVERSE-TYPE PITOT TUBE
VELOCITY PRESSURE GAUGE
CYCLONE
IMPINGERS
ICE BATH
SILICA GEL
VACUUM LINE
TI
FINE CONTROL VALVE
VACUUM GAUGE
V
COARSE VALVE
DRY TEST METER
AIR-TIGHT PUMP
ORIFICE GAUGE

FIGURE 4

PARTICULATE SAMPLING TRAIN

7.2 NITROGEN OXIDE

Using method 7, gas samples were withdrawn from the stack into evacuated 2-liter flasks containing a dilute solution of hydrogen peroxide and sulfuric acid. The hydrogen peroxide oxidizes the lower oxides of nitrogen (except nitrous oxide) to nitric acid. The resultant solution is evaporated to dryness and treated with phenol disulfonic acid reagent and ammonium hydroxide. The yellow trialkali salt of 6-nitro-1-phenol-2, 4-disulfonic acid is formed, which is measured colorimetrically.

7.3 SULFURIC ACID MIST AND SULFUR DIOXIDE

The "Shell Method"* was chosen for this determination due to uncertainties which exist about the validity of the results using method 8. A gas sample is drawn from the stack using a heated probe and passed through a water-cooled, coil condenser maintained below the dew point of sulfuric acid at 140°-194°F, followed by a fritted glass plate and then passed through a chilled impinger train with two impingers containing an isopropanol and hydrogen peroxide mixture and followed by an impinger containing silica gel for drying. This setup is shown in Figure 5.

The condensed sulfuric acid mist in the coil condenser is water washed from the condenser. The final determination is made by titrating the solution with barium chloride, using a thorin indicator. Isopropanol must be added to the solution to be titrated to improve the rapidity with which the barium sulfate precipitates during titration.

Sulfur dioxide in the gas sample is oxidized to sulfur trioxide the impingers containing the hydrogen peroxide. Sulfur dioxide is then determined by titrating the hydrogen peroxide solution with barium chloride, using a thorin indicator.

---

*Lisle, E.S. and J.D. Sensenbaugh, "The Determination of Sulfur Trioxide and Acid Dew Point In Flue Gases", Combustion, Jan. 1965.

Goksøyr, H. and K. Ross "The Determination of Sulfur Trioxide in Flue Gases", J. Inst. Fuel, No. 35, 177, (1962)

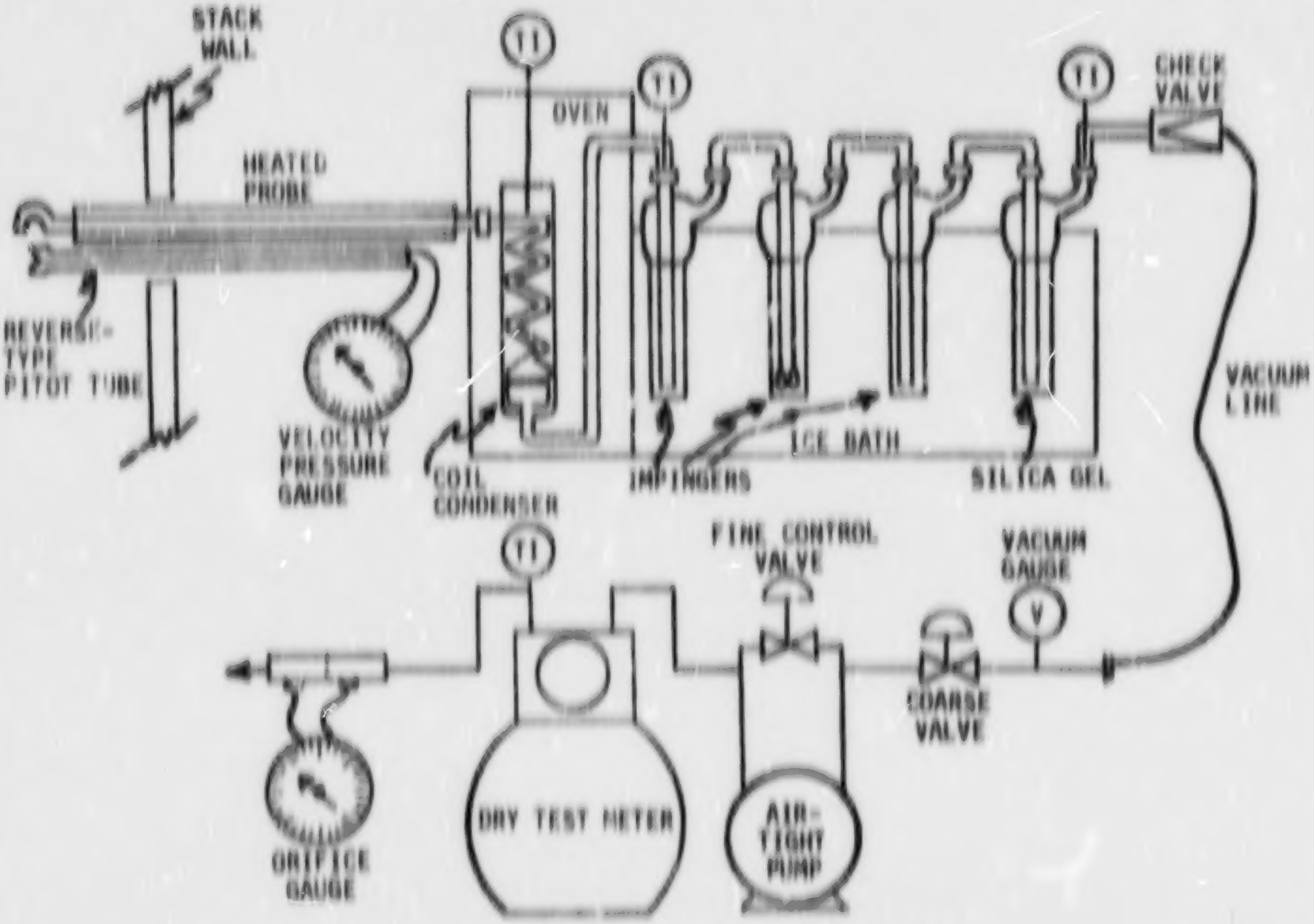
STACK WALL
HEATED PROBE
REVERSE-TYPE PITOT TUBE
VELOCITY PRESSURE GAUGE
TI
OVEN
COIL CONDENSER
TI
IMPINGERS
ICE BATH
SILICA GEL
TI
CHECK VALVE
VACUUM LINE
TI
FINE CONTROL VALVE
VACUUM GAUGE
V
COARSE VALVE
ORIFICE GAUGE
DRY TEST METER
AIR-TIGHT PUMP

FIGURE 5

SULFURIC ACID MIST SAMPLING TRAIN

7.4 PARTICLE SIZE

An Andersen, fractionating, inertial impactor is used for the determination of particle size in the range of approximately 0.5 to 10.0 microns. The sampling head is placed either in the stack at the end of the sampling probe or in the oven after the heated sample probe (see Figure 6). A sample of stack gas is drawn isokinetically through the sampler. The particulate matter is fractionated and collected on the plates inside the sample head and a determination is made by the difference in weight of the plates before and after testing. Results are expressed for particles of unit density.

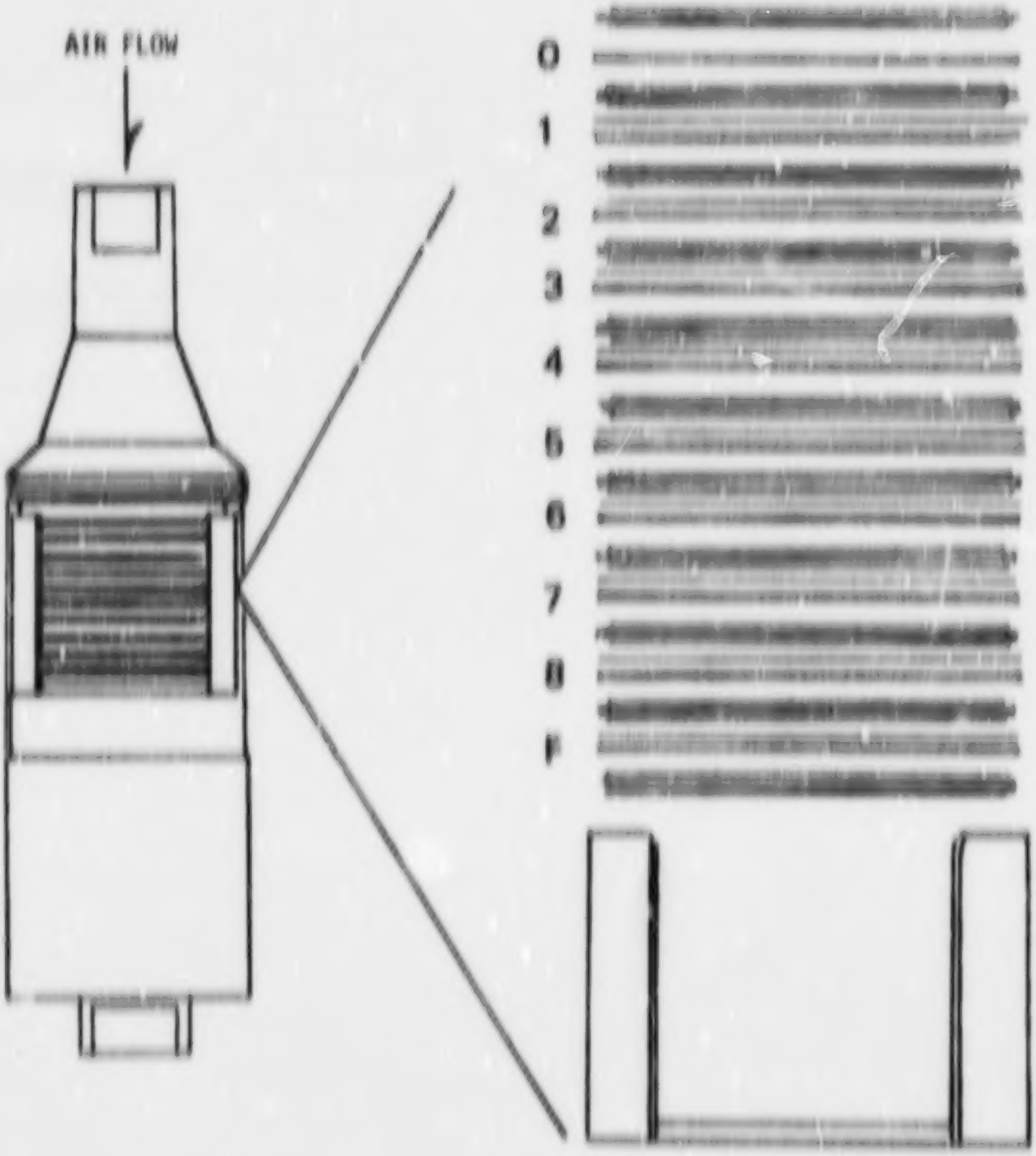
AIR FLOW
0
1
2
3
4
5
6
7
8
F

FIGURE 6
ANDERSEN STACK SAMPLER

8.0 RESULTS

The results obtained from this test are summarized in Table 1. As discussed previously, the main flow of pollutant is based on calculated, rather than measured flow rates. The actual calculations and field data are attached as Appendixes A and B. Although these tests were performed for research purposes and not as part of compliance procedures, standard EPA methods were used (except as indicated). It is thus of interest to compare the results obtained with State of Illinois standards. A comparison is shown in Table 2.

TABLE 1

Boiler 3 - Highland Power
SUMMARY OF RESULTS

Date	7/15/76	7/16/76			
Stack Flow Rate - SCFM * dry	15182	16962			
% Water Vapor - % Vol.	8.798	8.55			
% CO_2 - Vol % dry	14.0	11.8			
% O_2 - Vol % dry	4.3	5.2			
% Excess air @ sampling point	24.7	30.8			
SO_2 Emissions - lbs/10^6 Btu	5.9				
NO_x Emissions - lbs/10^6 Btu	0.17	0.24			
H_2SO_4 Mist - lbs/10^6 Btu	0.04				
Particulates Probe, Cyclone, & Filter Catch					
lbs./hr.	16.08				
lbs/10^6 Btu	0.22				
Total Catch					
lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling	92.67				

*70° F, 29.92" Hg
Calculated, dry

TABLE 2

COMPARISON OF RESULTS

Pollutant	Standard lbs/10^6BTU	Found lbs/10^6BTU
SO_2	1.8	5.9
NO_x	no standard for sources $\leq 250x10^6$BTU/hr	0.19
Particulates	0.23	0.22

The only minor constituent measured during this test was sulfuric acid mist which was determined to be 0.04 lbs/10^6 BTU.

In addition to measuring particulate loadings, a particle size analysis was made using an Andersen impactor. The results are shown in Tables 3 and 4 and Figure 7. The high percentage of particles less than 0.5 microns in diameter is probably spurious. Microscopic examination indicates the presence of large ammonium sulfate particles, which apparently were performed by subsequent reactions of ammonia with sulfuric acid. The latter, present in vapor form at stack temperature, was apparently retained by the glass fiber filter. The results for the first few plates on runs 2 and 3 are misleading since the cyclone was ahead of the Andersen impactor and it fairly effectively removes the larger particles.

Some of the photomicrographs are included for illustration. Figure 8 is of the total particulate filter from the run on 15 July. It shows bits of unburned to partially burned coal and sulfate needles. Figure 9 is from stage 5 of the impactor and shows small carbonaceous particles and sulfates, which are the white, shiny areas. Figure 10 is from stage 6 of the impactor and shows less carbonaceous particles and much more sulfate particles. The sulfate particles are definitely recrystallized on the filter since they follow filter fibers and are much larger than the impactor plate holes would allow.

TABLE 3

PARTICLE SIZE DETERMINATION

Test: No. 1 HIGHLAND POWER Date: July 16, 1975

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	20.4711	20.4745	3.4			5.6	100.0	13.12 & Above
2	21.4703	21.4755	5.2			8.7	94.4	8.96
3	21.6021	21.6108	8.7			14.5	85.7	6.02
4	22.8136	22.8178	4.2			7.0	71.2	4.61
5	11.7377	11.7412	3.5			5.8	64.2	2.64
6	11.4886	11.4904	1.8			3.0	58.4	1.34
7	11.7399	11.7418	1.9			3.1	55.4	0.83
8	21.4084	21.4150	6.6			11.0	52.3	0.55
Back Up Filter				24.8		41.3	41.3	<0.55
		Total	35.3	24.8	60.1	100.0		

Test: No. 2 Date: July 16, 1975

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	20.1914	20.1918	0.4			1.8	100.0	12.64 & Above
2	21.3706	21.3707	0.1			0.4	98.2	7.46
3	21.6880	21.6884	0.4			1.8	97.8	5.27
4	22.3718	22.3721	0.3			1.3	96.0	3.56
5	11.6965	11.6972	0.7			3.1	94.7	2.34
6	11.6807	11.6813	0.6			2.6	91.6	1.17
7	11.6864	11.6876	1.2			5.3	89.0	0.71
8	20.9210	20.9251	4.1			18.1	83.7	0.48
Back Up Filter				14.8		65.6	65.6	<0.48
		Total	7.8	14.8	22.6	100.0		

TABLE 4

PARTICLE SIZE DETERMINATION

Test: No 3 Highland Power Date: July 16, 1976

Plate	Tare(g)	Final(g)	Net(mg)	Plate ~~Filter~~ Net	Total	% of Total	Cum %	ECD (Microns)	
1	0.1436	0.1442	0.6	1.1	1.7	4.8	100.0	12.87	[illegible]
2	0.1496	0.1498	0.2	1.4	1.6	4.5	95.2	8.07	
3	0.1482	0.1487	0.5	0.8	1.3	3.6	90.7	5.65	
4	0.1476	0.1482	0.6	1.1	1.7	4.8	87.1	3.98	
5	0.1480	0.1490	1.0	0.8	1.8	5.0	82.3	2.24	
6	0.1802	0.1812	1.0	0.9	1.9	5.3	77.3	1.18	
7	0.1497	0.1520	2.3	1.0	3.3	9.2	72.0	0.78	
8	0.1470	0.1538	6.8	0.7	7.5	21.0	62.8	0.47	
Back Up Filter	0.2110	0.2232	12.2	2.7	14.9	41.8	41.8	<0.47	
		Total	25.2	10.5	35.7	100.0			

Test: Date:

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)	
1				0.6		2.4	100.0	12.87	[illegible]
2				0.2		0.8	97.6	8.07	
3				0.5		2.0	96.8	5.65	
4				0.6		2.4	94.8	3.98	
5				1.0		4.0	92.4	2.24	
6				1.0		4.0	88.4	1.18	
7				2.3		9.1	84.4	0.78	
8				6.8		27.0	75.3	0.47	
Back Up Filter				12.2		48.3	48.3	<0.47	
		Total		25.2		100.0			

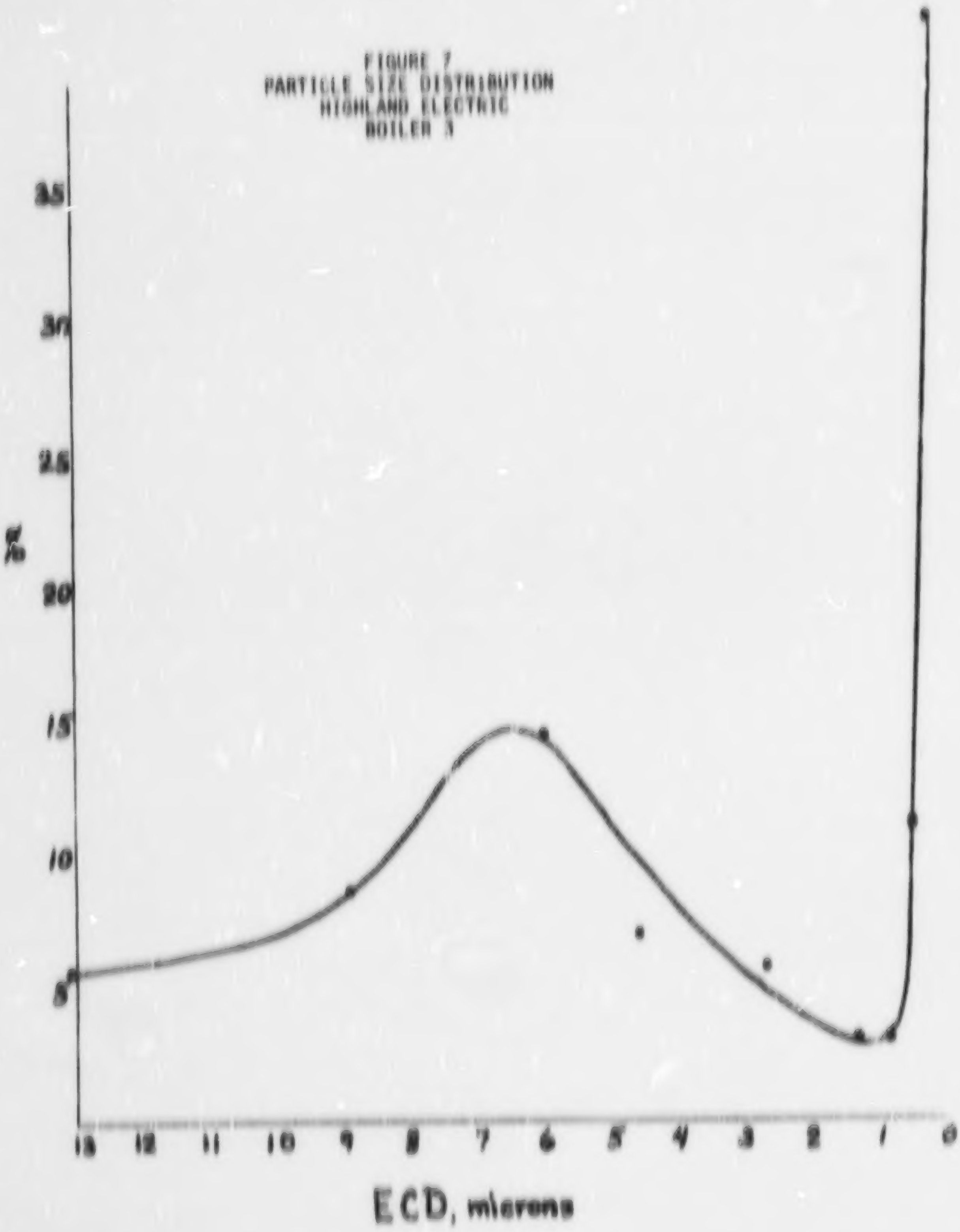

FIGURE 7
PARTICLE SIZE DISTRIBUTION
HIGHLAND ELECTRIC
BOILER 3

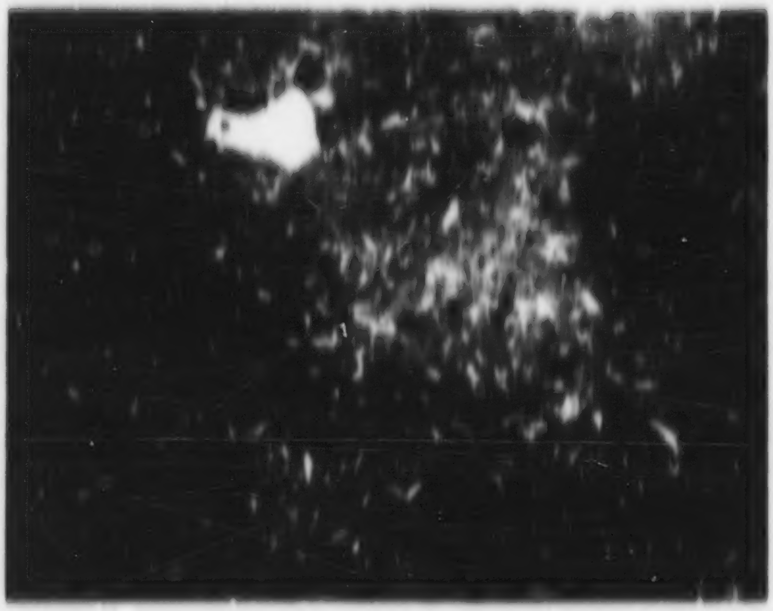

FIGURE 8

TOTAL PARTICULATE FILTER

FIGURE 9

SMALL CARBONACEOUS PARTICLES AND SULFATES FROM STAGE 5 OF ANDERSEN IMPACTOR. WHITE SHINY PARTICLES ARE SULFATES.

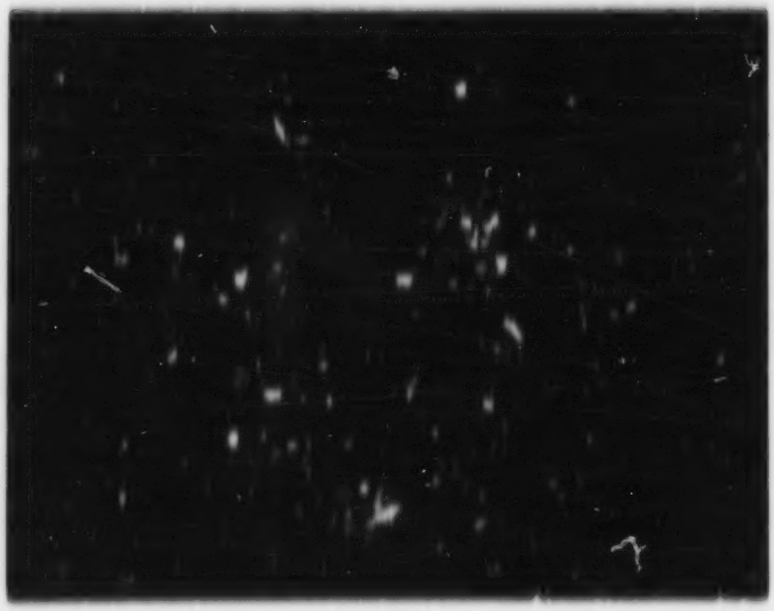

FIGURE 10

CARBONACEOUS PARTICLES AND SULFATES FROM STAGE 6 OF ANDERSEN IMPACTOR. NOTE INCREASE IN AMOUNT OF SULFATE FROM STAGE 5 TO STAGE 6.

Figure 11 is the backup filter for the impactor and it shows mostly sulfates with some very fine carbonaceous particles. Figure 12 is of material collected in the cyclone. There are a large variety of particle sizes, although somewhat misleading due to agglomeration of particles, and there is the presence of fused and partially fused glassy material and minerals.

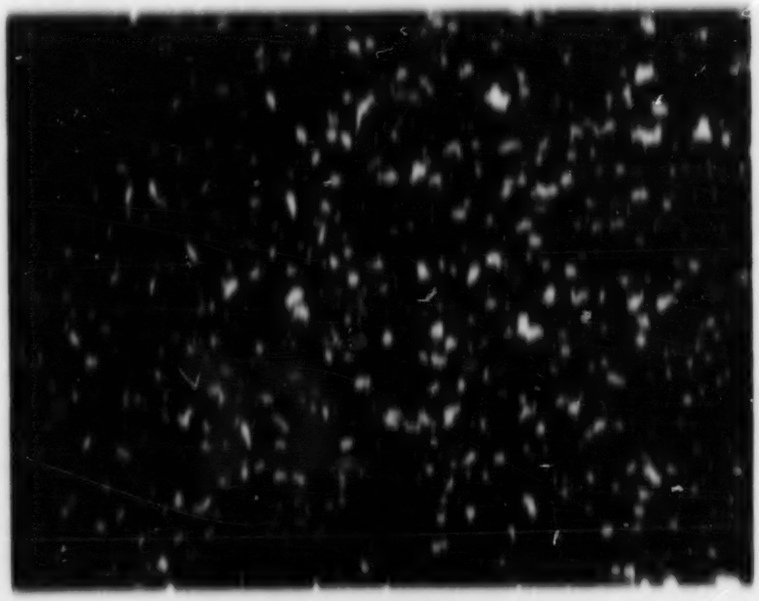

FIGURE 11
ANDERSEN IMPACTOR BACK-UP FILTER SHOWING VERY FINE CARBONACEOUS MATERIAL AND A GREAT NUMBER OF SULFATE CRYSTALS.

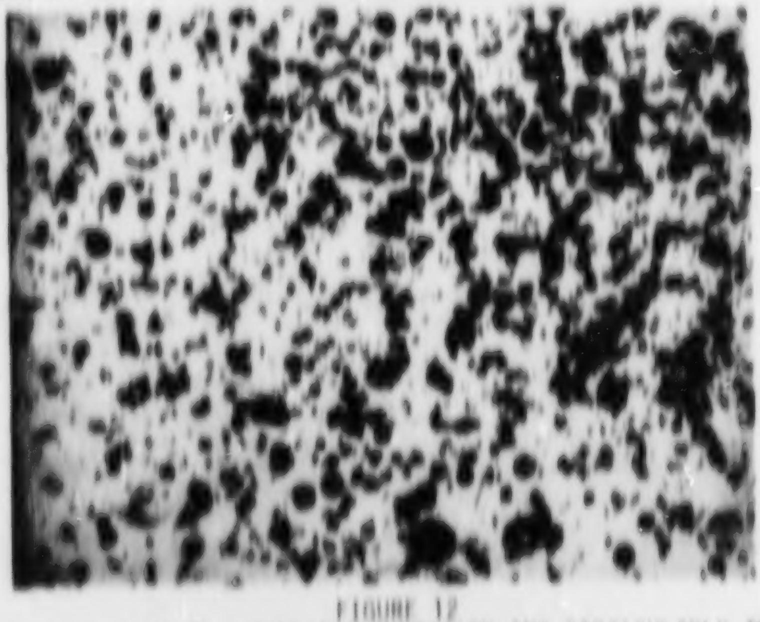

FIGURE 12
CYCLONE COLLECT. NOTE AGGLOMERATION AND PARTICULARLY THE SPHERES OF FUSED GLASSY PARTICLES.

APPENDIX A
PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70° F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{CF_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530° R or 70° F

Tm = Meter temperature, 530° R for compensated meter

CFm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = Vl_c\left(\frac{\rho H_2O}{MH_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right)\ \frac{lb.}{454\ gm.} = 0.0474 \times Vl_c$$

Vw = Volume of water vapor at standard conditions, ft^3

Vl_c = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

$M\ H_2O$ = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - °R

% Moisture in Stack Gas

$$\%\ M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\% O_2 \times \frac{32}{100}\right) + \left(\% N_2 \times \frac{28}{100}\right)$$

Molecular weight of stack gas

$$MW_W = \left(\frac{100 - \% M}{100} \times MW_D\right) + \left(\frac{\% M}{100} \times 18\right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{Ts \times \Delta P \text{ avg.}}{Ps \times MW_W}\right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{ft.}{sec.} \left(\frac{lb.}{lb. \text{ Mole} - {}^{o}R}\right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, ^{o}R

P_s = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Qs = 3600\left(1 - \frac{\%M}{100}\right) V_s \; A\left(\frac{Tstd}{Ts} \; \frac{Ps}{Pstd}\right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Qs' = Q_s \div 60$ = SCFM

Per cent isokinetic sampling

$$I = \frac{1.667 \left[(0.00267) \quad V_{lc} \quad + \quad \frac{V_m}{T_m} \left(P_b \quad + \frac{\Delta H}{13.6} \right) \right] T_s}{\theta \; V_s \; P_s \; A_n}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$0.00267 = \frac{\rho_{H_2O}}{M_{H_2O}} \quad X \quad R \quad X \quad \frac{lb.}{454 \; gm.}$

θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$C_s = 2.205 \quad X \quad 10^{-6} \left(\frac{M_n}{Vm_{std}} \right)$

C_s = particulate emission, lb/scf

$2.205 \; X \; 10^{-6}$ = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_S \; X \; Q_S$ = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% \, EA = \frac{100 \times \% \, O_2}{(0.266 \times \% \, N_2) - \% \, O_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: # 1 Date: 1/15/7[illegible]

Material collected (mg) =

Filter Catch = 0.7757
Dry Catch = 0.1017
Acetone Wash = 0.0593
0.9367
TOTAL = 936.7 mg

Gas Volume $Vm_{std} = 0.0334 \left(\frac{Vm}{1.021}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334\left(\frac{118.16}{1.021}\right)\left(30.16 + \frac{1.60}{13.6}\right) = \underline{117.056}$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

0.0474 (238.2 ml) = $\underline{11.291}$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(11.291)}{(117.056) + (11.291)} = \underline{8.798}$ %

Molecular Weight of dry stack gas

MW $MW_D = \%\,CO2 \times 0.44 + \%\,O2 \times 0.32 + \%\,N2 \times 0.28$

$(14.0 \times 0.44) + (4.3 \times 0.32) + (81.7 \times 0.28) = \underline{30.412}$

Molecular weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.798}{100} \times 30.412\right] + \left[\frac{8.798}{100} \times 18\right] = \underline{29.316}$

PARTICULATE SAMPLING CALCULATIONS

Test: Highland - #3 Boiler **Date:** 7/15/75

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times \Delta P\ avg}{P_s \times Mw_w}\right]^{1/2}$

$85.48 \times (0.84) \left[\frac{965 \times 0.267}{30.14 \times 29.320}\right]^{1/2} =$ 39.598 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%M}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(8.798)}{100}\right](39.598)\ (19.63)\ \frac{530}{(965)}\ \frac{(30.2)}{29.92} =$ 1,386,071 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(936.7)}{(117.036)} =$ 1.7647×10^{-5} lb/scf

$C_E = C_s \times Q_s = (1.765 \times 10^{-5})\ (1,386,071) =$ 24.46 lb/hr

$C_H = C_E \div H = \frac{(24.46)}{(74.76)} =$ 0.326 lb/10^6 Btu

Isokinetic Variations $I = \frac{1.667\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right]T_s}{\theta\ V_s\ P_s\ A_n}$

$\frac{1.667\left[(0.00267)\ (234.2) + \frac{116.819}{530}\left(30.2 + \frac{1.6}{13.6}\right)\right](965)}{(140)\ (39.598)\ (30.2)\ (3.67 \times 10^{-4})} =$ 92.6%

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (4.3)}{(0.266 \times 81.7) - (4.3)} =$ 24.7

STOICHIOMETRIC
FLOWRATE CALCULATION

Boiler #3

	Coal Composition		mols/100#		mols O_2 required
	S	3.25%	÷ 32	x 1	= 0.102
7/15/75	H_2O	12.89	÷ 18 = 0.716		
	Ash	10.98			
	Btu	10856 Btu/lb			
	C	61.63%	÷ 12	x1	= 5.136
5/27/67	H_2	4.37	÷ 2 = 2.185	x 0.5	= 1.093
	N_2	0.77	÷ 28 = 0.028		
	O_2	8.86	÷ 32	x -1	= -0.277
			Theoretical O_2		6.054

Excess air = 24.7% excess O_2 = 1.495

7.549

N_2 = 3.76 x O_2 =28.384

Mols Flue Gas = $CO_2 + SO_2 + N_2 + O_2 + N_2$
= 5.136 + 0.102 + 0.028 + 1.495 + 28.384 = 35.145 mols

Flue Gas = 35.145 x 386.7 $\frac{ft^3}{mol}$ = 13590.6 SCF/100#

@ 6702.4 lb coal/hr = 6702.4 x $\frac{1}{100}$ x 13590.6 = 910,896 SCFH
= 15,182 SCFM

Sulfur Check - SO_2 emissions

by emission factor 6702.4 ÷ 2000 x 38 x 3.25 = 413.9 #/hr SO_2

using calculated flow

910,896 x 4.75 x 10^{-4} $\frac{lb}{SCF}$ = 432.6 #/hr SO_2

NO_x EMISSION DATA

Date 2/13/73

Run No.	1	2	3	4	5	6	7	8
Time	[illegible]	[illegible]	[illegible]	1110	1300	1340	1400	[illegible]
µg NO_2	492	428	[illegible]	326	[illegible]	[illegible]	326	346
T_i - Initial Flask Temp, °F	70							
T_f - Final Flask Temp, °F	110							
V_{fc} - Flask Volume, ml.	2047	2018	2019	2024	2028	2026	2034	2051
P_i - Initial Flask Pres, "Hg	2.50							
P_f - Final Flask Pres, "Hg	30.2							
lb/scf NO_2 $\times 10^{-5}$	1.771	1.542	1.415	1.165	1.358	0.657	1.170	1.240
lb/10^6Btu NO_2	0.22	0.19	0.18	0.15	0.20	0.08	0.15	0.16

$$Vsc = \left(17.71 \frac{°R}{in.\ Hg}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = scf$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{lb/scf}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = lb/scf\ NO_2$$

NO_x EMISSION DATA

Date 2/16/78

Run No.	1	2	3	4				
Time	0945	1224	1120	1340				
µg NO_2	554	472	562	472				
T_i - Initial Flask Temp, °F	90	—	—	—				
T_f - Final Flask Temp, °F	120	—	—	—				
V_{fc} - Flask Volume, ml.	2047	2028	2039	2018				
P_i - Initial Flask Pres, "Hg	1.58	—	—	—				
P_f - Final Flask Pres, "Hg	29.4	—	—	—				
lb/scf NO_2 $\times 10^{-8}$	1.981	1.727	1.996	1.717				
lb/10^6Btu NO_2	0.26	0.22	0.26	0.23				

$$V_{sc} = \left(17.71 \frac{°R}{\text{in. Hg}}\right) \quad (V_{fc}) \quad \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \ \frac{\text{lb/scf}}{\mu\text{g/ml}} \left(\frac{\mu\text{g } NO_2}{V_{sc}}\right) = \text{lb/scf } NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	7/18	7/18	7/18			
Run No.	1	2	1+2			
V_{mc}-Meter Volume, Ft^3	6.237	5.731	11.968			
Vmstd-Meter Volume, Std. Cond.	6.163	5.683	11.846			
P_B-Barometric Pressure, "Hg	30.2	30.2				
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1	0.1				
V_t-Vol. of Titrant, ml.	1.8	1.8	31.92			
V_{tb}-Vol. of Titrant for Blank, ml.	nil	nil	nil			
Vsoln-Vol. of Solution, ml.	250	250	250			
V_a-Vol. of Aliquot, Titrated, ml.	25	25	10			
lb/scf H_2SO_4 $\times 10^{-6}$	3.15	3.42				
lb/10^6 Btu H_2SO_4	0.04	0.04				
lb-scf SO_2 $\times 10^{-4}$			4.75			
lb/10^6 Btu SO_2			5.9			

$$\text{Vmstd} = 0.0334\ \frac{(V_m)}{CF_m}\left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4}\ \frac{\text{lb-l}}{\text{g-ml}}\right)(V_t - V_{tb})\ (\underline{N})\ \left(\frac{V_{soln}}{V_a}\right)}{V_{mstd}} = \text{lb/scf}$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5}\ \frac{\text{lb-l}}{\text{g-ml}}\right)(V_t - V_{tb})\ (\underline{N})\ \left(\frac{V_{soln}}{V_a}\right)}{V_{mstd}} = \text{lb/scf}$$

APPENDIX B

FIELD DATA

SUPPLEMENTARY PROCESS & EMISSION DATA FOR POWER PLANTS

Test number	7/15/75	7/16/76		
Net Unit Load - ~~MW~~ KW	4188.9	4457.1		
Boiler Heat Rate - BTU/KW hr.				
Boiler Heat Input - 10^6 BTU/hr.	72.76	77.4		
Emission Level - lb./10^6 BTU				
Particulates				
SO_2				
NO_x				
Fuel Heating Value - BTU/lb.	10856	10856		
Fuel Burning Rate During Test - lb./hr.	6702.4	7131.4		
Fuel Ash Content - %	10.98	10.98		
Additive Rate - lb/hr.				

7/15

time	KW
9	4600
10	4400
11	4200
12	4100
1	4100
2	4000
3	4000
4	4000
5	4100
	4188.9

7/16

time	KW
9	5000
10	4100
11	4200
12	4300
1	4300
2	4600
3	4600
	4457.1

Fuel Consumption Basis : 1.6 lb Coal / 1 KW

Calculated Flow Rates : 7/15 910,896 SCFH
7/16 1,017,736 SCFH

ORSAT FIELD DATA

Location *Highland, Ill.* Comments:

Date *7.15.75*

Time

Operator *Klein*

	Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
7.15.75	0845 hrs	14.0/14.0	18.2/4.2	18.2/0.0
	1235 hrs.	14.0/14.0	18.4/4.4	18.4/0.0
7.16.75	1005 hrs	11.4/11.4	16.0/4.6	16.0/0.0
	1330 hrs.	12.2/12.2	18.0/5.8	18.0/0.0

Plant [illegible] Pacific Co.

Run No. 1

Location #3 Boiler Stack

Date 7/15/75

Operator Gibson/Olson

Sample Box No. ______

Meter Box No. ______

Meter ΔH@ 1.022

C Factor 0.55

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 85

Bar. Press. "Hg 30.2

Assumed Moisture % 8

Heater Box Setting °F 310°

Probe Tip Dia., In. 3/8

Probe Length 5FT. GLASS

Probe Heater Setting 310°

Avg. ΔP .18 Avg. ΔH ______

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg. H2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:06	746.091	0.02	0.12	0.13	200	75	1.0	310	245	0.22	135
2	11	747.50	.08	.47	.47	225	70	3.0	305	310		535
3	16	749.85	.12	.74	.74	245	70	4.3	320	322		550
4	21	753.1	.12	.74	.74	265	70	4.3	340	310		560
5	26	756.1	.20	1.20	1.20	280	72	7.0	385	325		570
6	31	759.9	.12	.74	.74	285	73	4.3	325	340		565
7	36	763.0	.12	.74	.74	285	75	4.3	320	320		560
8	41	766.5	.35	2.40	2.20	255	76	12.0	335	340		560
9	46	770.4	.37	2.3	2.25	310	77		360	360		560
10	51	775.8	.40	2.5	2.25	315	82		370	340		560
11	56	780.9	.40	2.5	2.25	320	83	13.0	365	330		560
12	01	785.8	.35	2.2	2.20	320	84	13.0	360	335		560
13	06	790.3	.34	2.1	2.10	320	85		310	330		560
14	11	795.4	.35	2.2	2.20	320	87	13.0	335	320		560
OFF	11:16	800.853										

Plant Hammond [illegible] Co.

Run No. 1

Location #2 [illegible]

Date [illegible]

Operator ____________

Sample Box No. ____________

Meter Box No. ____________

Meter ΔH@ ____________

C Factor ____________

PARTICULATE FIELD DATA

VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F ____________

Bar. Press., "Hg ____________

Assumed Moisture % ____________

Heater Box Setting °F ____________

Probe Tip Dia., In. ____________

Probe Length ____________

Probe Heater Setting ____________

Avg. ΔP ______ Avg. ΔH ______

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-1	12:44	800.958	0.12	1.2	1.2	200	80	8.0	315	280		280
2	49	804.6	.24	1.4	1.4	252	68	9.5	320	315		510
3	54	808.8	.24	1.4	1.4	275	70	9.5	325	325		550
4	59	813.0	.24	1.4	1.4	280	75	9.5	345	330		550
5	04	817.1	.26	1.52	1.52	290	75		300	335		
6	09	821.5	.30	1.8	1.8							
7	14	826.3	.34	2.0	2.0	290	78	12.5	340	325		550
8	19	831.1	.34	2.0	2.0	290	73		346	330		550
9	24	836.1	.33	2.0	2.0							
10	29	840.8	.33	2.3	2.1	295	75		355	335		550
11	34	845.5	.35	2.1	2.1	320	75	13.5	355	348		550
12	39	850.3	.34	2.0	2.0	310	78		360	360		545
13	44	855.0	.34	2.2	2.2	335	75	13.5	365	366		540
2-14	49	859.6	.29	1.9	1.9	315	80	12.0	360	325		530
[illegible]	1:54	864.132										

PARTICULATE CLEANUP SHEET

Date: 9/17/85
Plant: Highland Power Co.
Run Number: 1
Location Of Sample Port: [illegible]
Operator:
Barometric Pressure: 30.20 in Hg
Sample Box No.
Ambient Temperature 90°F

Impinger H2O

Volume After Sampling 301 ml
Impinger Prefilled With 200 ml
Volume Collected 101 ml

Silica Gel

Weight After 537.2 g
Weight Before 500.0 g w/ TARE
Moisture Weight 37.2 g Moisture Total 138.2 g

Dry Probe and Cyclone Catch:
Container No.
Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:
Container No.
Extra No. Weight Results 0.7029 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
11			

Filter Particulate Weight 0.2338 g

Total Particulate Weight 0.9367 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 7-12-75

Plant Nighman Electric Boiler #3

Sample Collected By Klein

Run No

Power Stat Setting

Field Data

Clock Time	9:15	10:06	10:31	11:18	1:00	1:40	2:00	[illegible]
Flask number	1	2	3	4	5	6	7	11
Volume of flask less correction (ml)	2047	2038	2039	2025	2035	2032	2014	[illegible]
Pressure before sampling [illegible] ~~in.~~ Hg.	6.5	6.5	6.0	5.8	6.3	6.2	6.1	6.1
Pressure after sampling, in. Hg (atm.)	30.20	30.20	30.20	30.20	30.20	30.17	30.17	[illegible]
Flask temperature, °F	90	9[illegible]	90	90	90	90	90	9[illegible]

OXIDES OF NITROGEN FIELD DATA

Date 7/16/75

Plant HIGHLAND ELECTRIC

Sample Collected By

Run No.

Power Stat Setting

Field Data

Clock Time	0945	1040	[illegible]	1310				
Flask number	1	2	3	4				
Volume of flask less correction (ml)	2007	2018	2015	2018				
Pressure before sampling in. Hg.	6.5	6.5	6.5	6.5				
Pressure after sampling, in. Hg.	30.0	30.0	30.0	30.0				
Flask temperature, °F	90	90	90	90				

GAS SAMPLING FIELD DATA

Material Sampled For H_2SO_4 & SO_2

Date 7-13-73

Plant Highland Electric Co. Location Boiler #3

Bar. Pressure 30.2 "Hg Comments:

Ambient Temp 85 °F

Run No 1 Point 2-7

Power Stat Setting ______

Filter Used: Yes ______ No ____

Operator Grissing/[illegible]

Clock Time	Meter (Ft.³)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures				
				Stack	Probe	Coil	Impinger In	Impinger Out
3:35	862.102	0.30	0.1	570	290	70°	140°	90°
3:40	864.1	0.32	0.1	560	305		150°	85°
3:45	866.3	0.34	0.1	560	310	74°	135°	51°
3:50	867.3	0.34	0.1	550	320	71°	125°	58°
3:60	868.5	0.30	0.1	550	315		125°	80°
4:03	870.337							

Comments:

GAS SAMPLING FIELD DATA

Material Sampled For H_2S & SO_2

Date 8.15.75

Plant Highland   Location Stack 3

Bar. Pressure 30.2 "Hg   Comments:

Ambient Temp 85 °F

Run No 2   Run 2.7

Power Stat Setting ______

Filter Used: Yes ______ No ___

Operator Cassen / Klein

Clock Time	Meter (Ft.^{3})	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures				
				Stack	Probe	Coil	Impinger In	Impinger Out
4:18	870.337	0.30	0.1	550	320°	83°	130°	75°
4:23	871.3	0.30	0.1	550	320°		135°	70°
4:28	872.5	0.34	0.1	550	330°	82°	135°	72°
4:33	873.35	0.38	0.1	560	335°		135°	72°
4:38	874.25	0.35	0.1	560	340°	80°	150°	130°
4:43	875.20	0.3	0.1	560	340°		140°	135°
4:48	876.070					75°		

Comments:

Anderson Particle Size Test

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Higgins
Run No. 1
Location [illegible]
Date 7-16-75
Operator [illegible]
Sample Box No. ________
Meter Box No. ________
Meter ΔH@ 1.022
C Factor 0.52

Ambient Temp °F 80
Bar. Press. "Hg 30.20
Assumed Moisture % 10
Heater Box Setting °F ________
Probe Tip Dia., In. 3/8
Probe Length 5 ft [illegible]
Probe Heater Setting ________
Avg. ΔP 0.32 Avg. ΔH 1.7

backup filter #6

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-9	10:25	846.82	0.32		1.4	230	65	16.5	320			545
	:30	850.1		1.7	1.2	235	66		325			
	:35	855.5			1.1	255	70		335			
	:40	862.3			1.05	265	74	17.0	340			
end	10:45	[illegible]			1.05							

[illegible] used

Andersen Particle Size Test

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Highland Electric
Run No. 2
Location Boiler #3 Stack
Date 7-16-75
Operator Grimes/Blair
Sample Box No. ______
Meter Box No. ______
Meter ΔH@ 1.83
C Factor .56

Backup Filter #5

Ambient Temp °F 90
Bar. Press. "Hg 30.2
Assumed Moisture % 8
Heater Box Setting °F 345±6
Probe Tip Dia., In. 3/8
Probe Length 5 ft steel
Probe Heater Setting ______
Avg. ΔP .62 Avg. ΔH 1.3

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
			Start	Desired	Actual	Inlet	Outlet					Start
2.12	1252	891.27	.62	1.3					345			550
	1253	[illegible]			1.3				345			
	1255	894.0			1.3				345			
	1257	895.4			1.3				335			
	1259	897.1			1.3				335			
	1301	898.7			1.3				335			
	1303	900.1			1.3				335			
		900.31										

[illegible]

[illegible]: Particle Size Test

Plant Highland [illegible]

Run No. 3

Location: [illegible]

Date 7-16-75

Operator [illegible]

Sample Box No. ______

Meter Box No. ______

Meter ΔH@ ______

C Factor ______

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 90

Bar. Press. "Hg 30.2

Assumed Moisture % 8

Heater Box Setting °F ______

Probe Tip Dia., In. 3/8

Probe Length [illegible]

Probe Heater Setting ______

Avg. ΔP ______ Avg. ΔH ______

[illegible] Filter # [illegible]

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Stack Temp °F	Stack Press. In. Hg.	Stack Temp. °F
			[illegible]	Desired	Actual	Inlet	Outlet					[illegible]
2-12	[illegible]	[illegible]	.22	1.3					280			[illegible]
	2	[illegible]			1.3		70		325			
	4	[illegible]			1.3				325			
	6	[illegible]			1.3				325			
	8	[illegible]			1.3		70		330			
	[illegible]	[illegible]										

PARTICULATE CLEANUP SHEET

Date: 7/16/92 Plant: Highland Electric

Run Number: Analyses 1,2,3 Location Of Sample Port: #3 Boiler [illegible]

Operator: ______

Barometric Pressure: ______

Sample Box No. ______

Ambient Temperature ______

Impinger H2O

Volume After Sampling 261 ml

Impinger Prefilled With 200 ml

Volume Collected 61 ml

Silica Gel

Weight After 209.5 g

Weight Before 209.0 g

Moisture Weight .5 g Moisture Total 61.5 g

Dry Probe and Cyclone Catch:

Container No. ______

Extra No. ______ Weight Results ______ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No. ______

Extra No. ______ Weight Results 261.5 mg

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.

Filter Particulate Weight 118.4 mg

Total Particulate Weight 379.9 mg

~~% Moisture By Volume~~ Particulate Concentration

$V_{m_{std}} = (14.861 + 8.74 + 7.78) \times 0.0317 + 1.021 \times (30.3 + \frac{[illegible]}{13.6}) = 31.178$

$C_s = 2.205 \times 10^{-6} \left(\frac{379.9}{31.178}\right) = \underline{2.69 \times 10^{-5} \text{ lb/scf}}$

% Moisture 0.0474 × 61.5 = 2.915

$100 \times \frac{2.915}{(31.178 + 2.915)} = \underline{8.55}\ \%$

PRELIMINARY
SOURCE TEST REPORT
CARLING BREWING CO. - STAG BREWERY
BELLEVILLE, ILLINOIS
BOILER NO. 1

4 NOVEMBER 1975

TESTED BY: Rockwell International
R.W. Griscom
D.C. Klein
F.E. Littman

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1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report summarizes the results obtained on boiler No. 1 at the Stag Brewery in Belleville, Illinois. Some work remains on the combustion efficiency of the unit to better clarify some of the obtained results. A final report will be issued at that point.

The stack testing included the following pollutants: SO_2, particulates, NO_x, H_2SO_4, and hydrocarbons. Orsat analysis for CO_2, CO, and O_2 were also performed. Results of these tests are included in this report. Although these tests were not conducted to ascertain compliance with Illinois standards, it is of interest that the particulate emissions and the SO_2 emissions are just slightly above the limits.

We acknowledge and appreciate the excellent cooperation we obtained from the officials of the Stag Brewery.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the Stag Brewery in Belleville, Illinois. Testing was performed on boiler No. 1 on 11, 12 and 13 August and 15, 16 and 20 October 1975.

Boiler No. 1 is a coal fired, 50,000 pounds per hour steam generating unit. There are no emission controls on this unit. This boiler was sampled for total particulates, particle size, nitrogen oxides, sulfur dioxide, sulfuric acid mist, carbon dioxide, oxygen and hydrocarbons.

3.0 PROCESS DESCRIPTION

Boiler No. 1 was built by Henry Vogt Boiler Co. and was installed in 1939. It is equipped with a gravity fed, traveling grate stoker. Steam pressure is maintained at approximately 123 psi. The firing rate of the boiler is directly controlled by the steam requirements of the brewery. As a result, there is a considerable fluctuation in the steam load throughout the day. Boiler No. 1 is a natural draft unit and has no stack emission controls. The stack is of brick construction and is 225 feet tall and 8 feet inside diameter.

4.0 SOURCE TEST DESCRIPTION

Boiler No. 1 was tested in the ductwork between the boilers and the stack. This is a common duct for both boilers 1 and 2, however, boiler No. 2 was not in operation at the time of testing. The sampling location is illustrated in Figure 1.

The duct at this point is 52.5 inches wide by 102 inches deep. The cross-section of the duct at this point is not rectangular since fly ash is deposited at the bottom and sloped to one side. Sample points were chosen accordingly to avoid sticking the probe into this fly ash. In accordance with the EPA Standard Method 1, thirty-five sampling points were chosen, seven at each of five sampling ports. Five, 4-inch pipe nipples were installed on the duct for use as sampling ports.

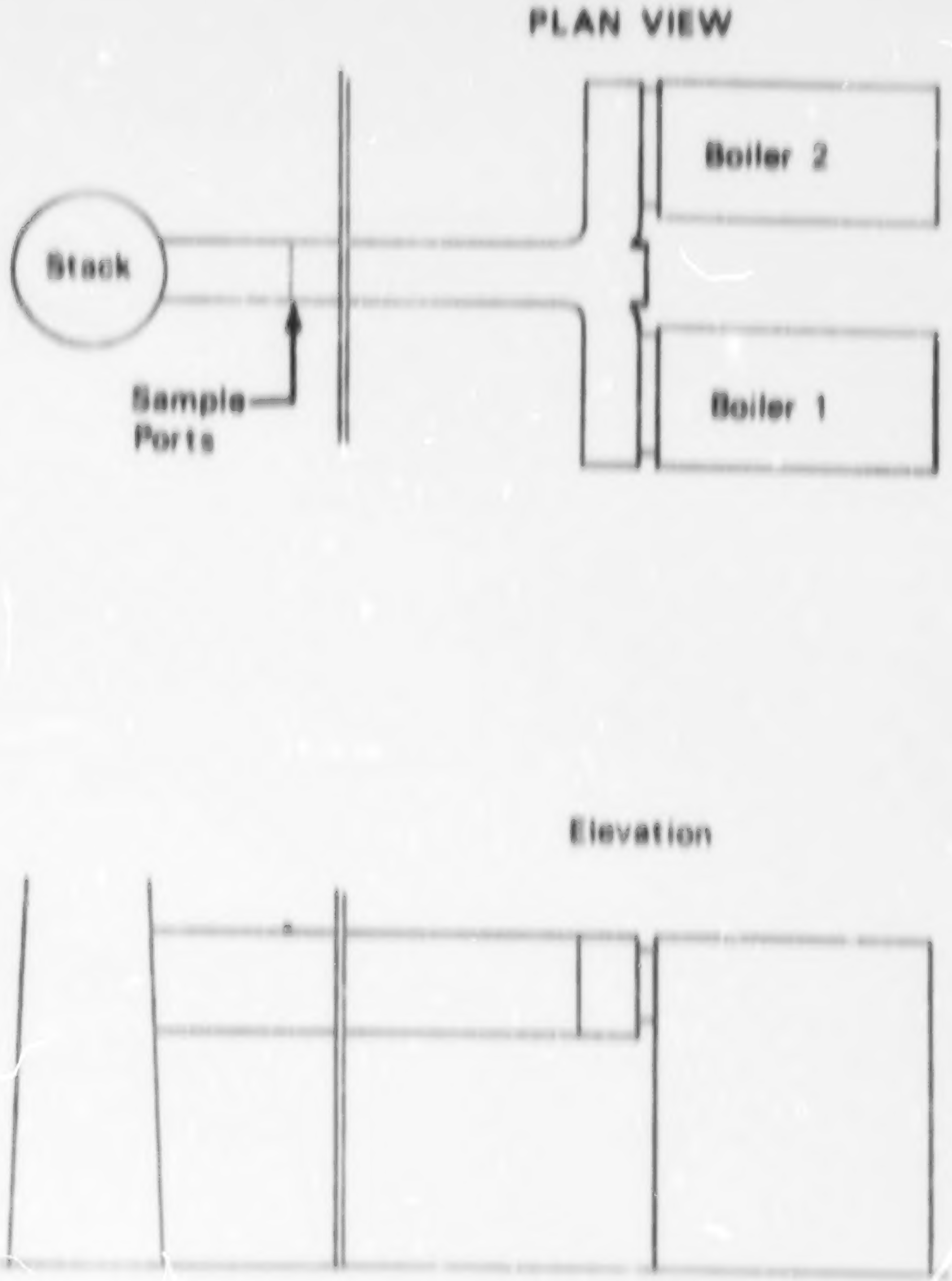
PLAN VIEW
Boiler 2
Stack
Sample Ports
Boiler 1
Elevation

FIGURE 1

SAMPLING LOCATION FOR BOILER NO. 1

5.0 PROCESS OPERATION

As mentioned previously, the firing rate on this boiler is determined by the steam requirements of the plant operation. As a consequence, load fluctuations of up to 100% occurred. During testing on 16 October, the boiler load was reduced considerably since no brewing operations were taking place that day. The load that day remained very constant. Ashes are pulled approximately once an hour. At those times the flow rate in the ductwork increased.

During testing in August, high sulfur coal was being burned; in October low sulfur coal, (1% S), was used.

6.0 DISCUSSION

Flow determinations were made in accordance with EPA Standard Method 2, using an S-Type Pitot Tube. This method gives correct results as long as the pitot tube is positioned normally to the flow of gases. This is no problem as long as the flow of gases is laminor and parallel to the walls of the ducts. However, if the flow is turbulent or vortex-type, the readings obtained are incorrect, with a positive bias (too high). The existence of a turbulent condition can be ascertained by turning the pitot tube 90° on its axis. A zero reading should then result. If no zero reading is obtained, the results are open to question.

In the duct being tested, the existence of turbulence was evident by the fact that a zero reading could not be obtained except on 16 October when the boiler was operated under reduced load. Actually, the flow rate on that day was not much lower than under full load conditions, but the gases consisted of a large excess of air and little combustion products. As a result, the flue gas temperature was lower.

Under conditions when satisfactory flow measurements cannot be obtained, a stoichiometric calculation of flow rates can be made, based on fuel consumption, fuel composition, combustion rate and excess air. As a check on the correctness of the assumption, the mass flow of SO_2 can be calculated based on gas flow and SO_2 concentration on one hand, and fuel consumption and sulfur analysis on the other. The conversion of sulfur in coal to SO_2 is straightforward and occurs with 95% efficiency.

To determine the amount of coal consumed, the steam output and a boiler efficiency were used to calculate coal consumption. The boiler efficiency was determined by comparing steam output to coal usage on thirteen high production day shifts. By this method an efficiency of 82.5% was determined.

Table 1 shows the comparison of the results obtained by the two methods.

TABLE 1
COMPARISON OF FLOW RATE DETERMINATIONS

DATE	FLOW RATE, SCFH Measured	Calculated	SO_2 (lbs/hr) BASED ON AP-42*	Calculated Flow	Measured Flow
8/12	1,354,989	782,909			
10/20		736,170	74.9	81.4	
10/20		776,420	79.0	91.1	

* Compilation of air pollutant.
Emission Factors, EPA Publ. No. AP-42

A small problem still remains in that these SO_2 emissions are still higher than predicted by emission factors. There is evidence to believe that the combustion efficiency of this boiler is very poor. If this is the case, then some amount of coal goes unburned. The stoichiometric flow rate determination is based upon complete combustion of the coal and, therefore, the actual flow rate would be less if combustion is not complete and the SO_2 emissions would be closer to the predicted results. This assumption will be evaluated shortly with a coal and ash analysis. Following this test, a final report on this installation will be completed.

7.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods. The following EPA methods were utilized during testing:

Method 1: Sample and Velocity Traverse
Method 2: Volumetric Flow Rate Determination
Method 3: Gas Analysis by Orsat Method
Method 4: Stack Gas Moisture Determination
Method 5: Determination of Particulate Emissions
Method 7: Determination of Nitrogen Oxide Emissions

In addition, a modified method 8 using the "Shell Method for Sulfuric Mist" was used for sulfuric mist and sulfur dioxide. Particle size determinations were made using an Andersen fractionating, inertial impactor. Hydrocarbon grab samples were taken.

9.0 RESULTS

The results obtained from this test are summarized in Table 2. As previously discussed, the pollutant emissions are based on calculated, rather than measured, flow rates. Although these tests were performed for research purposes and not as part of compliance procedures, standard EPA methods were used. It is thus of interest to compare the results obtained with State of Illinois standards. A comparison is shown in Table 3.

Since the measured flow rate is higher than the calculated flow rate, the testing for particulates was apparently conducted at greater than isokinetic conditions and the results are then higher than they should be. For this reason, it would appear that for the testing on 12 August, this boiler is very nearly within compliance.

The results of a sample taken on 6 August for hydrocarbon was:

Carbon Monoxide:	8.93 ppm
Methane:	0.33 ppm
Total Hydrocarbons, as CH_4:	6.97 ppm

The results of another sample for hydrocarbons taken on 11 August are given in Table 6. The total amounts to 7.14 ppm.

TABLE 2

SUMMARY OF RESULTS

Date	8/11	8/12	10/15	10/16	10/20
Stack Flow Rate - SCFM * dry	13048	13048	13604	12359	12635
% Water Vapor - % Vol.		9.02		4.7	
% CO_2 - Vol % dry		10.5	9.3	5.6	11.55
% O_2 - Vol % dry		10.4	10.0	14.8	8.7
% Excess air @ sampling point		97.7	103.3	232.2	69.5
SO_2 Emissions - lbs/10^6 Btu			2.4		2.35
NO_x Emissions - lbs/10^6 Btu	0.36	0.31			
H_2SO_4 Mist - lbs/10^6 Btu					0.031
Particulates Probe, Cyclone, & Filter Catch					
lbs./hr.		37.03		7.46	
lbs/10^6 Btu		0.95		0.37	
Total Catch					
lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling					

*70° F, 29.92" Hg

TABLE 3

COMPARISON OF RESULTS

POLLUTANT	ILLINOIS STATE STANDARDS lbs/10^6 BTU	FOUND lbs/10^6 BTU
SO^2	1.8	2.4, 2.3, 2.4
NO_x	No standard for sources <250 x 10^6 BTU/hr	0.36, 0.31
Particulates 8/12 10/16	0.28	0.95 0.37

In addition to measuring particulate loadings, a particle size analysis was made using an Andersen impactor. The results are shown in Tables 4 and 5.

TABLE 4
PARTICLE SIZE DETERMINATION

TEST: STAG - ANDERSEN #1 DATE: 8/13

PLATE	NET(mg)	FILTER NET	TOTAL	% OF TOTAL	CUM %	ECD (MICRONS)
1	13.7			18.6	18.6	12.28 & Above
2	10.6			14.3	32.9	7.72
3	6.4			8.7	41.6	5.15
4	4.9			6.6	48.2	3.63
5	2.6			3.5	51.7	2.23
6	3.1			4.2	55.9	1.15
7	1.5			2.0	57.9	0.70
8	10.9			14.8	72.7	0.47
BACK UP FILTER	20.2			27.3	100.0	<0.47
TOTAL	73.9	------ ------	------ ------	100.0		

TEST: STAG - ANDERSEN #2 DATE: 8/13

PLATE	NET(mg)	FILTER NET	TOTAL	% OF TOTAL	CUM %	ECD (MICRONS)
1	9.4			14.6	14.6	12.20 & Above
2	6.4			9.9	24.5	7.72
3	5.2			8.1	32.6	5.15
4	4.3			6.7	39.3	3.63
5	3.0			4.6	43.9	2.23
6	2.6			4.0	47.9	1.15
7	3.0			4.6	52.5	0.70
8	6.8			10.5	63.0	0.47
BACK UP FILTER	23.9			37.0	100.0	<0.47
TOTAL	64.6	------ ------	------ ------	100.0		

TABLE 5
PARTICLE SIZE DETERMINATION

TEST: STAG - ANDERSEN #3 DATE: 8/13

PLATE	NET(mg) PLATE	NET(mg) FILTER	TOTAL	% OF TOTAL	CUM %	ECD (MICRONS)
1	3.3	16.1	19.4	25.2	25.2	12.28 & Above
2	2.5	5.0	7.5	9.7	34.9	7.72
3	2.1	4.3	6.4	8.3	43.2	5.15
4	1.8	2.3	4.1	5.3	48.5	3.63
5	1.2	2.0	3.2	4.2	52.7	2.22
6	1.5	1.4	1.9	2.5	55.2	1.12
7	1.7	6.1	7.8	10.1	65.3	0.69
8	2.0	7.2	9.2	11.9	77.2	0.46
BACK UP FILTER		17.6	17.6	22.8	100.0	<0.46
TOTAL	16.1	62.0	77.1	100.0		

TEST: STAG - ANDERSEN #3 DATE: 8/13

PLATE	TARE(g)	FINAL(g)	NET(mg)	FILTER NET	TOTAL	% OF TOTAL	CUM%	ECD (MICRONS)
1				16.1		26.0	26.0	12.28 & Above
2				5.0		8.1	34.1	7.72
3				4.3		6.9	41.0	5.15
4		FILTERS ONLY		2.3		3.7	44.7	3.63
5				2.0		3.2	47.9	2.22
6				1.4		2.3	50.2	1.12
7				6.1		9.8	60.0	0.69
8				7.2		11.6	71.6	0.46
BACK UP FILTER				17.6		28.4	100.0	<0.46
TOTAL				62.0		100.0		

TABLE 6

HYDROCARBON ANALYSIS

TEST: STAG #1 DATE: 8/11/75 TIME:

COMPOUND	CONCENTRATION(ppb)
Ethane	76.6
Propane	67.3
Isobutane	46.5
1-Butene	29.2
n-Butane	28.2
Isopentane	4.9
1-Pentene	2.5
n-Pentane	5.4
2-Methyl Pentane	3.4
2-Methyl, 1-Pentene	2.8
1-Hexene	38.3
n-Hexane	115.1
3,3-dimethyl, 1-Pentene	22.9
2,4-dimethyl Pentane & Benzene	34.4
1 methylcyclopentene & 2M C3 Hexane	10.4
Cyclohexane	4.9
2-methyl Hexane	1.8
3-methyl Hexane	2.9
1-Heptene	8.6
n-Heptane	12.2
Toluene	49.9
2,2,5-trimethyl Hexane	3.4
1-Octene	6.8
n-Octane	3.6
Ethylbenzene	37.3
meta, para Xylene	72.2
Orthoxylene	18.9
n-Nonane	6.3
n-Propylbenzene	4.7
1,2,4 Trimethyl Benzene	3.5

APPENDIX A

PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70° F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{CF_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530° R or 70° F

Tm = Meter temperature, 530° R for compensated meter

CFm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = Vl_c\left(\frac{\rho H_2O}{M H_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right)\frac{lb.}{454\ gm.} = 0.0474 \times Vl_c$$

Vw = Volume of water vapor at standard conditions, ft^3

Vl_c = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

$M\ H_2O$ = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - °R

% Moisture in Stack Gas

$$\%\ M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\% CO_2 \times \frac{44}{100} \right) + \left(\% O_2 \times \frac{32}{100} \right) + \left(\% N_2 \times \frac{28}{100} \right)$$

Molecular weight of stack gas

$$MW_W = \left(\frac{100 - \% M}{100} \times MW_D \right) + \left(\frac{\% M}{100} \times 18 \right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{Ts \times \Delta P \text{ avg.}}{Ps \times MW_W} \right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{ft.}{sec.} \left(\frac{lb.}{lb.\ Mole - {}^{\circ}R} \right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, °R

P_s = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Qs = 3600 \left(1 - \frac{\% M}{100} \right) V_s \ A \left(\frac{Tstd}{Ts} \ \frac{Ps}{Pstd} \right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Qs' = Q_s / 60$ = SCFM

Per cent isokinetic sampling

$$I = \frac{1.667\left[(0.00267)\ V_{lc} + \frac{V_{mc}}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right] T_s}{\theta\ V_s\ P_s\ A_n}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$0.00267 = \frac{\rho H_2O}{M_{H_2O}}$ X R X $\frac{lb.}{454\ gm.}$

θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$C_s = 2.205\ X\ 10^{-6}\left(\frac{M_n}{Vm_{std}}\right)$

C_s = particulate emission, lb/scf

2.205 X 10^{-6} = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_s$ X Q_s = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% EA = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: Stag - Boiler #1 **Date:** 4/18/78

Material collected (mg)

Filter Catch = 163.2
Dry Catch =
Acetone Wash = 1509.0

TOTAL = 1672.2

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \frac{(81.027)}{(1.01)}\left(29.30 + \frac{1.4}{13.6}\right) = \underline{78.792}$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

$0.0474\ (163\ ml) = \underline{7.726}$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(7.726)}{(78.792) + (7.726)} = \underline{8.93}$ %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(10.5 \times 0.44) + (10.4 \times 0.32) + (79.1 \times 0.28) = \underline{30.20}$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.93}{100} \times 30.2\right] + \left[\frac{8.93}{100} \times 18\right] = \underline{29.11}$

PARTICULATE SAMPLING CALCULATIONS

Test: Stag Boiler #1 **Date:** [illegible]

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times P\ avg}{P_s \times M_{w}}\right]^{1/2}$

$85.48 \times (0.84) \left[\frac{997.7 \times 0.679}{29.17 \times 29.11}\right]^{1/2} =$ 22.183 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{B_w}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(6.92)}{100}\right](22.183)\ (16.44)\ \frac{530}{(997.7)}\ \frac{(29.\ )}{29.92} =$ [illegible] SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{([illegible])}{([illegible])} =$ [illegible] lb/scf

$C_E = C_s \times Q_s =$ ([illegible]) ([illegible]) = [illegible] lb/hr

$C_H = C_E \div H = \left(\frac{[illegible]}{[illegible]}\right) =$ [illegible] lb/10^6 Btu

Isokinetic Variations $I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right] T_s}{\theta\ V_s\ P_s\ A_n}$

$1.667 \frac{\left[(0.00267)\ (16.\ ) + \frac{[illegible]}{530}\left(29.1 + \frac{1.9}{13.6}\right)\right](997.7)}{([illegible])\ (22.183)\ ([illegible])\ ([illegible])} =$ [illegible]

Excess Air at Sample Point

$\% EA = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$

$\frac{100\ (3.8)}{(0.266 \times [illegible]) - (3.8)} =$ [illegible]

STOICHIOMETRIC
FLOWRATE CALCULATIONS

Boiler #1 6/12/75

	Coal Composition Peabody-River King		Mols/100#			Mols O_2 required
	S	3.25%	÷ 32	x 1	=	0.102
7/15/75	H_2O	12.89	÷ 18 = 0.716			
	Ash	10.98				
	Btu	10856 Btu/lb				
	C	61.63	÷ 12	x 1	=	5.136
	H_2	4.37	÷ 2 = 2.185	x .5	=	1.093
5/27/67	N_2	0.77	÷ 28 = 0.028			
	O_2	8.86	÷ 32	x -1	=	-0.277
				Theoretical O_2		6.054
	@ 97.7 % Excess air				=	5.915 11.969
	N_2 = 3.76 x O_2				=	45.003 56.972

Mols Flue Gas = 5.136 + 0.102 + 5.915 + 45.003 + 0.028 = 56.184 mols

$$56.184 \times 386.7 \frac{ft^3}{mol} = 21726.4 \text{ SCF/100\# coal @ } 70^{\circ}\text{F, 1atm.}$$

6/12/75 31.775×10^3 #/hr steam @ 82.5% boiler eff.
1193.8 Btu/# 125 psig; sat. steam
-178.1 Btu/# 210°F water
1015.7 But/#

$$\frac{31.775 \times 10^3 \times 1015.7}{.825} = 3.91198 \times 10^7 \text{ Btu/hr input}$$

$3.91198 \times 10^7 \div 10856 = 3603.5$ #/hr coal

$3603.5 \times \frac{1}{100} \times 21726.4 = 782909.1$ SCFh, dry

NO_2 EMISSION DATA

Date [illegible]

Run No.	1	2	3	4	5	6		
Time	1306	1410	1412	1422	1445	1470		
μg NO_2	544	564	471	516	388	348		
T_i - Initial Flask Temp, °R	[illegible]							
T_f - Final Flask Temp, °R	[illegible]							
V_{fc} - Flask Volume, ml.	2047	2016	2019	2022	2018	2011		
P_i - Initial Flask Pres, "Hg	4.06							
P_f - Final Flask Pres, "Hg	21.16							
lb/scf NO_2 $\times 10^{-6}$	1.94	2.08	1.71	1.74	1.47	1.41		
lb/10^6 Btu NO_2	0.44	0.41	0.34	0.36	0.29	0.29		

$$V_{sc} = \left(17.71 \frac{°R}{in.\ Hg}\right) (V_{fc}) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = scf$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{lb/scf}{\mu g/ml} \left(\frac{\mu g\ NO_2}{V_{sc}}\right) = lb/scf\ NO_2$$

NO_x EMISSION DATA

Date 8/12/78

Run No.	1	2	3	4	5	6	9	10
Time	1215	1220	1520	1525	1530	1535	1550	1555
μg NO_2	408	428	--	388	346	346	444	470
T_i - Initial Flask Temp, °R	90	—	—	—	—	—	—	
T_f - Final Flask Temp, °R	120	—	—	—	—	—	—	
V_{fc} - Flask Volume, ml.	2072	2063		2083	2050	2017	2179	2052
P_i - Initial Flask Pres, "Hg	2.66	—	—	—	—	—	—	
P_f - Final Flask Pres, "Hg	29.10	—	—	—	—	—	—	
lb/scf NO_2 $\times 10^{-5}$	1.53	1.61		1.47	1.31	1.29	1.66	1.82
lb/10^6Btu NO_2	0.31	0.32		0.29	0.26	0.26	0.33	0.37

$$Vsc = \left(17.71 \frac{°R}{in.\ Hg}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = scf$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5}\ \frac{lb/scf}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = lb/scf\ NO_2$$

PARTICULATE SAMPLING CALCULATIONS

Andersen Run 1, 2, 3

Test: Slag - Boiler #1 **Date:** 8/13/75

Material collected (mg)

Filter Catch = 242.8
Dry Catch =
Acetone Wash = 49.6

TOTAL = 292.4

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{1.897}{1.01}\right)\left(24.6 + \frac{1.4}{13.6}\right) = \underline{24.208}$ SCF

Volume of water vapor Vw = 0.0474 X Vlc

0.0474 (61.0 ml) = 2.891 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(2.891)}{(24.208) + (2.891)} = \underline{10.67}$ %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

(11.2 X 0.44) + (4.2 X 0.32) + (79.6 X 0.28) = 30.16

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 10.67}{100} \times 30.16\right] + \left[\frac{10.67}{100} \times 18\right] = \underline{28.86}$

PARTICULATE SAMPLING CALCULATIONS

Test: Boiler #1 - Andersen 1, 2, 3 **Date:** 8/13/75

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times \Delta P\ avg}{P_s \times Mw_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{1048.7 \times 0.08}{29.37 \times 28.86}\right]^{1/2} =$ 22.877 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%M}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(10.67)}{100}\right](22.878)\ (36.82)\ \frac{530}{(1048.7)}\ \frac{(29.37)}{29.92} =$ 1,373,480 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \left\{\frac{292.4}{24.262}\right\} =$ 2.66×10^{-5} lb/scf

$C_E = C_s \times Q_s = (2.66 \times 10^{-5})\ \ (1,373,480) =$ 36.54 lb/hr

$C_H = C_E \div H = \left\{\frac{36.54}{45.416}\right\} =$ .806 lb/10^6 Btu

Isokinetic Variations $I = \frac{1.667\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right]T_s}{\theta\ V_s\ P_s\ A_n}$

$\frac{1.667\left[(0.00267)\ \ (61.0) + \frac{44.38}{530}\left(29.5 + \frac{1.4}{13.6}\right)\right](1048.7)}{(30)\ \ (22.877)\ \ (29.37)\ \ (1.36 \times 10^{-3})} =$ 98.6%

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (9.2)}{(0.266 \times 79.6) - (9.2)} =$ 76.8%

Hydrocarbon Results

Test: Stag #1 Boiler Date: 8/6 Time:

Carbon Monoxide: 8.93 ppm

Methane: 0.35 ppm

Total Hydrocarbons, as CH_4: 6.97 ppm

Test: Date: Time:

Carbon Monoxide: ppm

Methane: ppm

Total Hydrocarbons, as CH_4: ppm

Test: Date: Time:

Carbon Monoxide: ppm

Methane: ppm

Total Hydrocarbons, as CH_4: ppm

Test: Date: Time:

Carbon Monoxide: ppm

Methane: ppm

Total Hydrocarbons, as CH_4: ppm

APPENDIX B

FIELD DATA

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Date	8/11 - 8/13			
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr				
Boiler Heat Input				
Fuel Burning Rate - lb/hr				
Fuel Heating Value - BTU/lb	10876			
Fuel Sulfur Content - %	3.18			
Fuel Ash Content - %	10.78			
Fuel Moisture Content %	14.89			

8/11 NOx

31.775×10^3 lb/hr steam
39.12×10^6 Btu/hr
3603.8 lb/hr coal
782909 SCFH

8/13 Andersen 1,2,3

36.889×10^3 lb/hr steam
45.476×10^6 Btu/hr
4183.0 lb/hr coal
811669 SCFH

8/12 NOx + Part

31.775×10^3 lb/hr steam
39.12×10^6 Btu/hr
3603.6 lb/hr coal
782929 SCFH

ORSAT FIELD DATA

Location *Stag Brewery* Comments:

Date *8.12.75*

Time

Operator

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
# 1115	10.6	24.2/13.6	24.2
1240	1[illegible].0	20.6/ 8.6	20.6
1535	9.0	21.2/12.2	21.2
avg.	10.8	10.4	0.0

# There is reason to believe that this number is not valid and has been eliminated from the average.

ORSAT FIELD DATA

Location Stag Brewery   Comments:

Date 8 13 75

Time

Operator

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
1045	11.6	20.8/9.2	20.8
1200	10.8	20.0/9.2	20.0
avg.	11.2	9.2	0.0

Plant Stag Brewery

Run No. 2

Location Power House Stack

Date 8-12-75

Operator Gregory/Klein

Sample Box No. ____

Meter Box No. ____

Meter ΔH@ 1.026

C Factor ____

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 90

Bar. Press. "Hg 29.30

Assumed Moisture % 10.5

Heater Box Setting °F 45

Probe Tip Dia., In. 1/2 inch

Probe Length 10 ft

Probe Heater Setting 7

Avg. ΔP 0.08 Avg. ΔH 1.4

Point	Clock	Dry Gas Meter, CF	Pitot in H₂O ΔP	Orifice ΔH in H₂O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg. H₂O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:30	1070.655	0.06	1.05	1.05	160	80	8.0	310	90	0.9	590
1-2	:33	1072.	0.06	1.05	1.05	190	70		320	160		590
1-3	:36	1075.0	0.06	1.05	1.05	215	70	7.5	330	170		560
1-4	:39	1077.1	0.06	1.05	1.05	230	72		335			560
1-5	:42	1079.2	0.06	1.05	1.05	245	75		345			540
1-6	:45	1081.4	0.08	1.4	1.4	255	75		350			530
1-7	:48	1083.7	0.09	1.6	1.6	265	74	11.0	355			530
off	10:51	1086.255										
2-1	11:30	1086.255	0.07	1.2	1.2	200	85	8.5	340	95		565
2-2	:33	1088.5	0.07	1.2	1.2	250	71		345	160		560
2-3	:36	1090.8	0.08	1.4	1.4	260	73	10.0	350	180		580
2-4	:39	1093.1	0.09	1.6	1.6	265	77	11.3	355	185		580
2-5	:42	1095.7	0.10	1.75	1.75							
2-6	:45	1098.3	0.11	1.9	1.9	285	80	14.0	365	200		570
2-7	:48	1101.2	0.10	1.75	1.75	290	80		375	210		570
off	11:51	1103.890										

10:55 - 11:25 Blowing ash

Run # 2

Point	Clock Time	Dry Gas Meter CF	Pitot In H2O ΔP	Orifice ΔH In H2O		Impinger °F Temp		Pump Vacuum In Hg Gauge	Box Temp °F	Impinger Temp °F	Stack Press. In Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
3-1	12-30	1102.590	0.07	1.2	1.2	200	80	5.5	305	400		450
3-2	33	1104.1	0.07	1.2	1.2	220	75		320	150		460
3-3	36	1106.0	0.07	1.2	1.2	240	75		325	170		520
3-4	39	1108.4	0.08	1.4	1.4	250	75		325			520
3-5	42	1110.9	0.08	1.4	1.4	260	75		340	185		510
3-6	45	1115.4	0.09	1.6	1.6	265	75		340			570
3-7	48	1118.0	0.10	1.75	1.75	270	77	13.0	345	190		580
off	12:51	1120.615										
4-1	2:25	1120.615	0.05	0.9	0.9	190	85	7.0	325	70		570
4-2	28	1122.6	0.06	1.05	1.05	230	75		320			520
4-3	31	1124.7	0.07	1.2	1.2	250	75	9.0	310			530
4-4	34	1127.1	0.08	1.4	1.4	250	75	10.5	310			560
4-5	37	1129.5	0.08	1.4	1.4	260	76		310			540
4-6	40	1132.0	0.09	1.6	1.6	260	75		320			560
4-7	43	1134.5	0.09	1.6	1.6	265	80		320			570
off	46											
5-1	3:16	1137.0	0.08	1.4	1.4	210	80	10.5	340			480
5-2	19	1139.6	0.07	1.2	1.2	240	75		345			450
5-3	22	1141.8	0.08	1.4	1.4	250	72		335			500
5-4	25	1144.3	0.08	1.4	1.4	250	75		330			510
5-5	28	1146.8	0.08	1.4	1.4	250	75		330	90		520
5-6	31	1149.1	0.09	1.6	1.6	255	75		330			540
off	34	Last point changing due to fly ash build up in duct										
		1151.692	1.56									11355
			0.078 avg									Avg. 567

120°

Comments: 12:45 - 1:00 Blowing ashes
Probe heat shorted again 4 & 5 traverse with heat off
3:30 - 3:45 Blowing ashes

PARTICULATE CLEANUP SHEET

Date: 8/12/[illegible]
Plant: Stag Brewery
Run Number: 2
Location Of Sample Port: #1 Boiler Duct
Operator: [illegible]
Barometric Pressure: 29.10
Sample Box No.
Ambient Temperature 90

Impinger H2O

Volume After Sampling 141 ml
Impinger Prefilled With 100 ml
Volume Collected 141 ml

Silica Gel

Weight After 222.3 g
Weight Before 200.0 g
Moisture Weight 22.3 g Moisture Total 163.3 g

Dry Probe and Cyclone Catch:
Container No.
Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:
Container No.
Extra No. Weight Results 1.5090 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
8			

Filter Particulate Weight 0.1632 g

Total Particulate Weight 1.6722 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 8/11/78

Plant Stag : Boiler #1

Sample Collected By Klein

Field Data

Clock Time	1200	1210	1415	1420	1425	1430		
Flask number	1	2	3	4	5	6		
Volume of flask (ml)*	2017	2018	2039	2026	2025	2012		
Pressure before sampling in. Hg.	2.66							
Pressure after sampling, in. Hg.	29.26							
Flask temperature, °F	120							

* Flask + valve - 25 ml. for absorbing solution

OXIDES OF NITROGEN FIELD DATA

Date 8/12/78

Plant Stag. Blr. #1

Sample Collected By Klein

Field Data

Clock Time	1415	1420	1520	1525	1530	1535	1540	1545
Flask number	1	2	3	4	5	6	9	10
Volume of flask (ml)*	2047	2030	-	2028	2026	2052	2054	2037
Pressure before sampling in. Hg.	2.66							
Pressure after sampling, in. Hg.	29.10							
Flask temperature, °F	120							

* Flask + valve - 25 ml. for absorbing solution

Anderson Particle Size

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Stag Brewery
Run No. Andersen #1
Location #1 Boiler Stack
Date 2/6/75
Operator Grissom / Klein
Sample Box No. ______
Meter Box No. ______
Meter Y 1.026
C Factor ______

Ambient Temp °F 40
Bar. Press. "Hg 29.30
Assumed Moisture % 10.5
Heater Box Setting °F ______
Probe Tip Dia., In. 1/2"
Probe Length 5 ft glass
Probe Heater Setting ______
Avg. ΔP 0.08 Avg. ΔH 1.4

Andersen in Oven, plates only

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O Desired	Orifice ΔH in H2O Actual	Impinger °F Temp. Inlet	Impinger °F Temp. Outlet	Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp. °F
3-3	10:50	1160.175	0.08	1.4	1.4	150	85	12.5	305	280		580
	:52	1161.8	0.08	1.4	1.4	175	70		315	315		580
	:54	-	0.08	1.4	1.4							
	:56	1165.0	0.08	1.4	1.4	220	78		335	330		590
	:58	1166.7	0.08	1.4	1.4	240	79		345	330		590
off	11:00	1168.382	0.08									535
		8.227 ft^3										

10:55 - Rolling Ashes

Anderson Particle Size

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Stag Brewery
Run No. Anderson #2
Location #1 Boiler Stack
Date 8/13/75
Operator Grison / Klein
Sample Box No. ______
Meter Box No. ______
Meter ΔH@ 1.826
C Factor ______

Anderson in oven, plates only

Ambient Temp °F 90
Bar. Press. "Hg 25.30
Assumed Moisture % 10.5
Heater Box Setting °F ______
Probe Tip Dia., In. ½
Probe Length 5 ft glass
Probe Heater Setting ______
Ref. ΔP ______ Ref. ΔH ______

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
3-6	11:48	1168.382	0.08	1.9	1.9	145	80	11.5	300	250		540
	:50	1170.1	0.08	1.9	1.9	190	68		320	310		550
	:52	1171.7	0.08	1.9	1.9	200	65		330	320		550
	:54	1173.2	0.08	1.9	1.9	215	68		340	330		550
	:56	1174.9	0.08	1.9	1.9	225	70		350	340		560
off	11:58	1176.610	0.08									
		8.228 cu										

Andersen Particle Size

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant: Stag Brewery
Run No. Andersen #3
Location: #1 Boiler Stack
Date: 8/12/75
Operator: Grisom/Klein
Sample Box No. ______
Meter Box No. ______
Meter Y: 1.026
C Factor ______

Ambient Temp °F: 90
Bar. Press. "Hg: 29.30
Assumed Moisture %: 10.5
Heater Box Setting °F: ______
Probe Tip Dia., In.: 1/2
Probe Length: 5 ft. glass
Probe Heater Setting: ______
Ref. ΔP ______ Ref. ΔH ______

Andersen in oven, plates with 2 thers

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
3-3	1:05	1176.640	0.08	1.4	1.4	170	73	12.0	310	325		582
	:07	1178.3	0.08	1.4	1.4	195	63		330	355		590
	:09	1180.0	0.08	1.4	1.4	205	60		335	360		590
	:11	1181.7	0.08	1.4	1.4	220	62	13.5	335	370		590
	:13	1183.3	0.08	1.4	1.4	235	65		335	360		560
off	1:15	1185.052	0.08									
		8.412 ft³										

1:13 - Pulling Ashes

PARTICULATE CLEANUP SHEET

Date: 8/13/78
Plant: Stag Brewery
Run Number: Andersen 1,2,3
Location Of Sample Port: #1 Boiler Du
Operator: Grisson/Klein
Barometric Pressure: 29.10
Sample Box No. ______
Ambient Temperature 90°

Impinger H2O

Volume After Sampling 250.5 ml
Impinger Prefilled With 200 ml
Volume Collected 50.5 ml

Silica Gel

Weight After 310.5 g
Weight Before 300.0 g
Moisture Weight 10.5 g Moisture Total 61.0 g

Dry Probe and Cyclone Catch:
Container No. ______
Extra No. ______ Weight Results ______ g

Probe, Cyclone, Flask And Front Of Filter Acetone Wash:
Container No. ______
Extra No. ______ Weight Results 48.6 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
Andersen	Plates & Filters		

Filter Particulate Weight 242.8 g

Total Particulate Weight 292.4 g

% Moisture By Volume

PARTICULATE SAMPLING CALCULATIONS

Test: Stag - Boiler #1   Date: 10/16/78

Material collected (mg)

Filter Catch =
Dry Catch =
Acetone Wash =

TOTAL =

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \frac{(55.48)}{(1.01)}\left(29.61 + \frac{0.516}{13.6}\right) =$ 54.365 SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

0.0474 (56 ml) = 2.654 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(2.654)}{(54.365) + (2.654)} =$ 4.66 %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

(5.6 X 0.44) + (14.8 X 0.32) + (79.6 X 0.28) = 29.488

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 4.66}{100} \times 29.488\right] + \left[\frac{4.66}{100} \times 18\right] =$ 28.953

PARTICULATE SAMPLING CALCULATIONS

Test: Stag - Boiler #1 **Date:** 10/16/78

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times \Delta P\ avg}{P_s \times M_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{942.2 \times 0.016}{29.60 \times 28.984}\right]^{1/2} =$ 14.60 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%H}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(14.6)}{100}\right](14.60)\ (.80)\ \frac{530}{(942.2)}\ \frac{(29.60)}{29.92} =$ 972,729 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(273.9)}{([illegible])} =$ 1.006×10^{-5} lb/scf

$C_E = C_s \times Q_s = (1.006 \times 10^{-5})\ (972,729) =$ 9.78 lb/hr

$C_H = C_E \div H = \frac{(9.78)}{(18.682)} =$ 0.54 lb/10^6 Btu

Isokinetic Variations $I = \frac{1.667\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right]T_s}{\theta\ V_s\ P_s\ A_n}$

$$\frac{1.667\left[(0.00267)\ (56) + \frac{55.44}{530}\left(29.61 + \frac{0.516}{13.6}\right)\right](942.2)}{(105)\ (14.6)\ (29.5)\ (1.356 \times 10^{-3})} = 93.0\%$$

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (14.8)}{(0.266 \times 79.6) - (14.8)} =$ 218.2%

STOICHIOMETRIC
FLOWRATE CALCULATIONS

Boiler #1 10/15/75

Coal Composition		mols/100#	mols O_2 required
C	65.00%	÷ 12 × 1	= 5.417
S	1.04	÷ 32 × 1	= 0.033
H_2	4.50	÷ 2 = 2.25 × 0.5	= 1.125
N_2	1.0	÷ 28 = 0.036	
O_2	7.94	÷ 32 = 0.248 x-1	= -0.248
Ash	8.34		
Moist	12.16	÷ 18 = 0.677	
Btu	10,390 Btu/lb		
		Theoretical O_2	= 6.327 mols
Excess air = 103.3%		excess O_2	= 6.536
		Total O_2	= 12.863
N_2 = 3.76 x O_2			= 48.364

Mols Flue Gas = $CO_2 + SO_2 + N_2 + O_2 + N_2$
= 5.417 + 0.033 + 0.036 + 6.536 + 48.364 = 60.386 mols

Flue Gas = 60.386 x 386.7 $\frac{ft^3}{mol}$ = 23,351.3 SCF/100#

@ 29.5 x 10^3 lb/hr steam = $\frac{29.5 \times 10^3 \times 1015.7}{0.825}$ = 36.319 x 10^6 BTU/hr

36.319 x 10^6 ÷ 10390 = 3495.6 lb/hr coal

3495.6 x $\frac{1}{100}$ x 23,351.3 = 816267 SCFH
= 13604 SCFM

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	10/18		10/20	10/20	10/20	10/20
Run No.	1		1	1	2	2
V_{mc}-Meter Volume, Ft^3	16.621		13.965		12.794	
Vmstd-Meter Volume, Std. Cond.	16.171		[illegible]		12.486	
P_B-Barometric Pressure, "Hg	29.48		29.51		29.51	
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1		0.1		0.1	
V_t-Vol. of Titrant, ml.	9.92		3.6	8.67	4.2	9.08
V_{tb}-Vol. of Titrant for Blank, ml.	nil		nil	nil	nil	nil
Vsoln-Vol. of Solution, ml.	250		100	250	100	250
V_a-Vol. of Aliquot, Titrated, ml.	1.0		20	1.0	20	1.0
lb/scf H_2SO_4 $\times 10^{-6}$			1.536		1.816	
lb/10^6 Btu H_2SO_4			0.029		0.034	
lb-scf SO_2 $\times 10^{-4}$	1.081			1.207		1.281
lb/10^6 Btu SO_2	2.4			2.3		2.4

$$\text{Vmstd} = 0.0334 \frac{(V_m)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$C_{H_2SO_4} = \frac{\left(1.08 \times 10^{-4} \frac{\text{lb-l}}{\text{g-ml}}\right) (V_t - V_{tb}) \ (N) \ \left(\frac{V_{soln}}{V_a}\right)}{V_{mstd}} = \text{lb/scf}$$

N = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{\text{lb-l}}{\text{g-ml}}\right) (V_t - V_{tb}) \ (N) \ \left(\frac{V_{soln}}{V_a}\right)}{V_{mstd}} = \text{lb/scf}$$

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Date	10/15	10/16	10/20-1	10/20-2
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr	29.5	17.83	32.0	33.75
Boiler Heat Input 10^6 Btu/hr	36.3	20.1	39.4	41.58
Fuel Burning Rate - lb/hr	34956	1933	3791.8	37.991
Fuel Heating Value - BTU/lb	10390	10390	10390	10390
Fuel Sulfur Content - %	1.04	1.04	1.04	1.04
Fuel Ash Content - %	8.34	8.34	8.34	8.34
Fuel Moisture Content %	12.18	12.18	12.18	12.18

Calculated Flow Rates:

10/15	816,267	SCFM
10/16	741,886	SCFM
10/20-1	736,170	SCFM
10/20-2	776,460	SCFM

ORSAT FIELD DATA

Location Stag - Boiler #1 Comments:

Date 10/15 & 10/16 & 10/20

Time

Operator Klein

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
10/15 1310	9.2	11.0	0.0
1350	9.4	10.6	0.0
10/16 1340	5.6	14.8	0.0
1130	8.8	9.0	0.0
10/20 1120	11.5	8.9	0.0
1135	11.6	8.5	0.0

Plant Stag

Run No. 1

Location Blr #1

Date 10/16

Operator Grissom, Klein

Meter ΔH@

C Factor

PARTICULATE FIELD DATA

VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Trouble with probe thermister, invalid readings

No heater brought today

Ambient Temp °F 70°

Bar. Press "Hg 29.60

Assumed Moisture % 2

Probe Tip Dia., In. 1/2

Probe Length 10 ft

Avg. ΔP Avg. ΔH

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:45	1705.760	0.42	0.4	0.4				325	125	-0.9	500
1-2	:48	1708.2	0.42	0.4	0.4	145	54	3.0	300	175		480
1-3	:51	1708.8	0.42	0.4	0.4	150	54		305	185		485
1-4	:54	1710.0	0.42	0.4	0.4	190	58		308	195		490
1-5	:57	1711.5	0.43	0.57	0.57	195	54		305	195		485
1-6	11:00	1713.2	0.54	0.77	0.77	205	56		310	200		490
1-7	:03	1715.3	0.445	0.65	0.65	130	54	6.0	320	230		485
off	11:06	1716.965										
2-1	11:15	1716.965	0.525	0.50	0.50	170	58	3.5	300	195		485
2-2	:18	1718.6	0.385	0.5	0.5	210	52		300	210		485
2-3	:21	1720.1	0.385	0.5	0.5	210	51		305	245		485
2-4	:24	1721.7	0.43	0.57	0.57	220	52	4.5	330	245		485
2-5	:27	1724.2	0.54	0.76	0.76	210	52		330	240		500
2-6	11:30	1726.7	0.54	0.76	0.76	215	52		320	230		505
2-7	:33	1727.1	0.495	0.85	0.85	230	53		330	230		500
off	11:36	1729.080										

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
3-1	12:49	1725.240	0.02	0.4	0.4	150	58	3.5	320	120		472
-2	:51	1726.5	0.02	0.4	0.4	205	59		320	200		478
-3	:54	1728.4	0.02	0.4	0.4	215	54		320	230		478
-4	:57	1730.3	0.02	0.4	0.4	215	54		320	225		475
-5	1:00	1734.8	0.025	0.5	0.5	225	54	4.0	325	240		480
-6	:03	1736.4	0.025	0.5	0.5	230	55		330	235		480
-7	:06	1737.9	0.025	0.5	0.5	225	55		335	240		475
off	1:09	1739.550										
4-1	1:45	1739.850	0.02	0.4	0.4	190	62	3.5	340	130		485
-2	:48	1740.9	0.02	0.4	0.4	205	57		340	195		480
-3	:51	1742.6	0.02	0.4	0.4	205	57		340	205		478
-4	:54	1744.8	0.025	0.5	0.5	215	57		335	205		470
-5	:57	1745.5	0.025	0.5	0.5	235	58		335	225		478
-6	2:00	1747.1	0.025	0.5	0.5	245	60		340	220		480
-7	:03	1748.7	0.04	0.77	0.77	240	60	5.5	340	205		480
off	2:06	1750.420										
5-1	2:47	1750.420	0.02	0.4	0.4	170	65	4.0	340	170		480
-2	:50	1751.2	0.02	0.4	0.4	225	60		335	210		480
-3	:53					220	60		335	245		485
-4	:56	1754	0.02	0.4	0.4							
-5	:59	1755	0.02	0.4	0.4	240	61		335	240		478
-6	3:02	1757.8	0.03	0.57	0.57	240	63		340	250		470
-7	:05	1759.7	0.02	0.57	0.57	250	65		340	250		460
off	3:08	1761.390										

COMMENTS: 35.44 cf 0.026 0.576 481.2°

PARTICULATE CLEANUP SHEET

Date: 10/16 Plant: Slag

Run Number: 1 Location Of Sample Port: Boil. #1

Operator: Grislow, Klein Barometric Pressure: 29.61

Sample Box No. ________ Ambient Temperature 70 °F

Impinger H2O

Volume After Sampling 241 ml

Impinger Prefilled With 200 ml

Volume Collected 41 ml

Silica Gel

Weight After 218.6 g

Weight Before 200.1 g

Moisture Weight 18 g Moisture Total 59 g

Dry Probe and Cyclone Catch:

Container No. ________

Extra No. ________ Weight Results ________ g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No. ________

Extra No. ________ Weight Results 0.1652

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
12			

Filter Particulate Weight 0.0819 g

Total Particulate Weight 0.2471 g

% Moisture By Volume

GAS SAMPLING FIELD DATA

Material Sampled For SO2 & SO3

Date 10/15/75

Plant Stag Location Boiler #1

Bar. Pressure 29.48 "Hg Comments: 29.48 in. Hg - ground

Ambient Temp 75 °F 29.445 in. Hg - stack

Run No 1

Power Stat Setting ______

Filter Used: Yes ______ No ____

Operator Grissom, Klein

Clock Time	Meter (Ft.³)	Pitot in. H2O ΔP	Orifice in H2O ΔH	Temperatures °F				
				Stack	Probe	Gold Oven	Impinger In	Impinger Out
12:55	1689.169	0.03	0.1	540	265	188	109	70
1:05	1692	0.04	0.1	550	275	183	117	61
1:15	1694.8	0.04	0.1	565	275	180	130	63
1:25	1697.15	0.05	0.1	565	275	170	124	63
1:35	1700.65	0.04	0.1	550	275	178	130	65
1:45	1703.15	0.02	0.1	540	275	170	126	66
1:55	1705.745							

Comments: 40000 lbs coal charged on 7-3 shift
avg. 29.5x10³ lb/hr steam

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 10/20/75

Plant Stag Location Boiler #1

Bar. Pressure ________ "Hg Comments: 29.808 in. Hg. ground

Ambient Temp 75 °F 29.468 in. Hg. stack

Run No 1

Power Stat Setting ________

Filter Used: Yes ________ No ____

Operator Carlson, Klein

Clock Time	Meter (Ft.³)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
11:10	1783.420	0.07	0.1	590	275	144	135	80
11:20	1785.6	0.05	0.1	575	325		160	70
11:30	1788.0	0.06	0.1	580	295		155	70
11:40	1790.1	0.05	0.1	570	310	168	142	67
11:50	1792.3	0.06	0.1	580	285		137	69
12:00	1794.4	0.055	0.1	530	275	166	124	68
12:10	1796.385					171		
	12.965 cf							

Comments: 1. Could not get a zero reading on the pitot apparently too much turbulence.

2. ΔP dropped off from 0.07 to 0.05 right after the operator stopped pulling ashes.

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 10/20

Plant Slag

Location #1 Boiler

Bar. Pressure 29.51 "Hg

Comments

Ambient Temp 75 °F

Run No 2

Power Stat Setting

Filter Used: Yes ______ No ______

Operator Coribian, Klein

Clock Time	Meter (Ft.³)	Pitot in. H₂O ΔP	Orifice in H₂O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger	
							In	Out
12:35	1796.366	0.03	0.1	505	275	150	110	69
12:45	1798.4	0.04	0.1	570	275	155	135	65
12:55	1800.7	0.035	0.1	560	290		130	68
1:05	1803.1	0.035	0.1	550	290		125	65
1:15	1805.2	0.04	0.1	570	295		120	64
1:25	1807.3	0.03	0.1	560	305	155	120	67
1:35	1809.160							

Comments: 12.794 CF

SOURCE TEST REPORT
GENERAL MOTORS ASSEMBLY DIVISION
ST. LOUIS, MISSOURI

BOILER NO. 2

TESTED BY: ROCKWELL INTERNATIONAL
R.W. Griscom
D.C. Klein
F.E. Littman

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FIGURE 8 SULFURIC ACID MIST SAMPLING TRAIN 227

FIGURE 9 SAMPLING UNIT WITH ANDERSEN SAMPLER IN OVEN 229

FIGURE 10 ANDERSEN STACK SAMPLER 230

FIGURE 11 PARTICLE SIZE DISTRIBUTION/BOILER 2 234

1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report details the results obtained on boiler no. 2 at the General Motors Assembly Plant in St. Louis, Missouri.

The stack testing included the following pollutants: SO_2 (sulfur dioxide), particulates, NO_x (nitrogen oxides), H_2SO_4 (sulfuric acid mist) and hydrocarbons. Orsat analysis for CO_2 (carbon monoxide), and O_2 (oxygen) were also performed. Results of these tests are included in this report. Although these tests were not conducted to ascertain compliance with St. Louis standards, it is of interest that the particulate emissions are within the limits. The SO_2 emissions standards are not applicable for this time of the year, nor for an individual boiler in an installation.

We acknowledge and appreciate the excellent cooperation we obtained from the engineering department and the power plant personnel at General Motors.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the General Motors Assembly Plant in St. Louis, Missouri. Testing was performed on boiler no. 2 on 8,9 and 10 September 1975.

Boiler no. 2 is a coal-fired, 80,000 pounds per hour steam generating unit. The unit is equipped with a cyclone, mechanical precipitator. This boiler was sampled for total particulates, particle size, NO_x, SO_2, H_2SO_4 CO_2 and O_2.

3.0 PROCESS DESCRIPTION

Boiler no. 2 was built by Union Iron Works and was installed in November 1952. It is equipped with a gravity fed spreader stoker. Steam pressure is maintained at approximately 166 psi. The firing rate is controlled to match the demands of the assembly plant. At shift changes the load drops off 20-25% for an hour or two. The capacity of this boiler is rated at 80,000 pounds of steam per hour.

This boiler is equipped with a Western Precipitation Multi-cyclone mechanical precipitator rated at 98% efficiency. Boiler no. 2 is an induced draft unit and uses a common stack with boilers 1, 3, and 4. The stack is of brick construction and is 225 feet tall and 13 feet inside diameter at the top.

This boiler and no. 4 boiler are equipped with caustic scrubbers for removing SO_2. These scrubbing units are in operation from October through March for compliance with the local St. Louis standards.

4.0 PROCESS OPERATION

Boiler no. 2 was tested 8 September to 10 September. During the testing period the boiler load remained fairly constant. Because of shift change, the load started to decrease between 2 and 2:30 PM. Testing was generally completed prior to 2 PM. Ashes were pulled on the boiler at approximately 11:30 AM and 1:30 PM each day.

5.0 SOURCE TEST DESCRIPTION

Boiler no. 2 was tested in the ductwork between the boiler and the stack and ahead of the takeoff for the SO_2 scrubber. The sampling location and testing arrangement are illustrated in Figures 1, 2, and 3.

The duct at this point is 49 inches wide by 5 feet high. This location was between four and five diameters from the last bend in the duct. In accordance with EPA Standard Method 1, thirty-two sampling points were chosen, eight at each of four sampling ports. General Motors already had four, 3-inch pipe couplings installed for use as sampling ports.

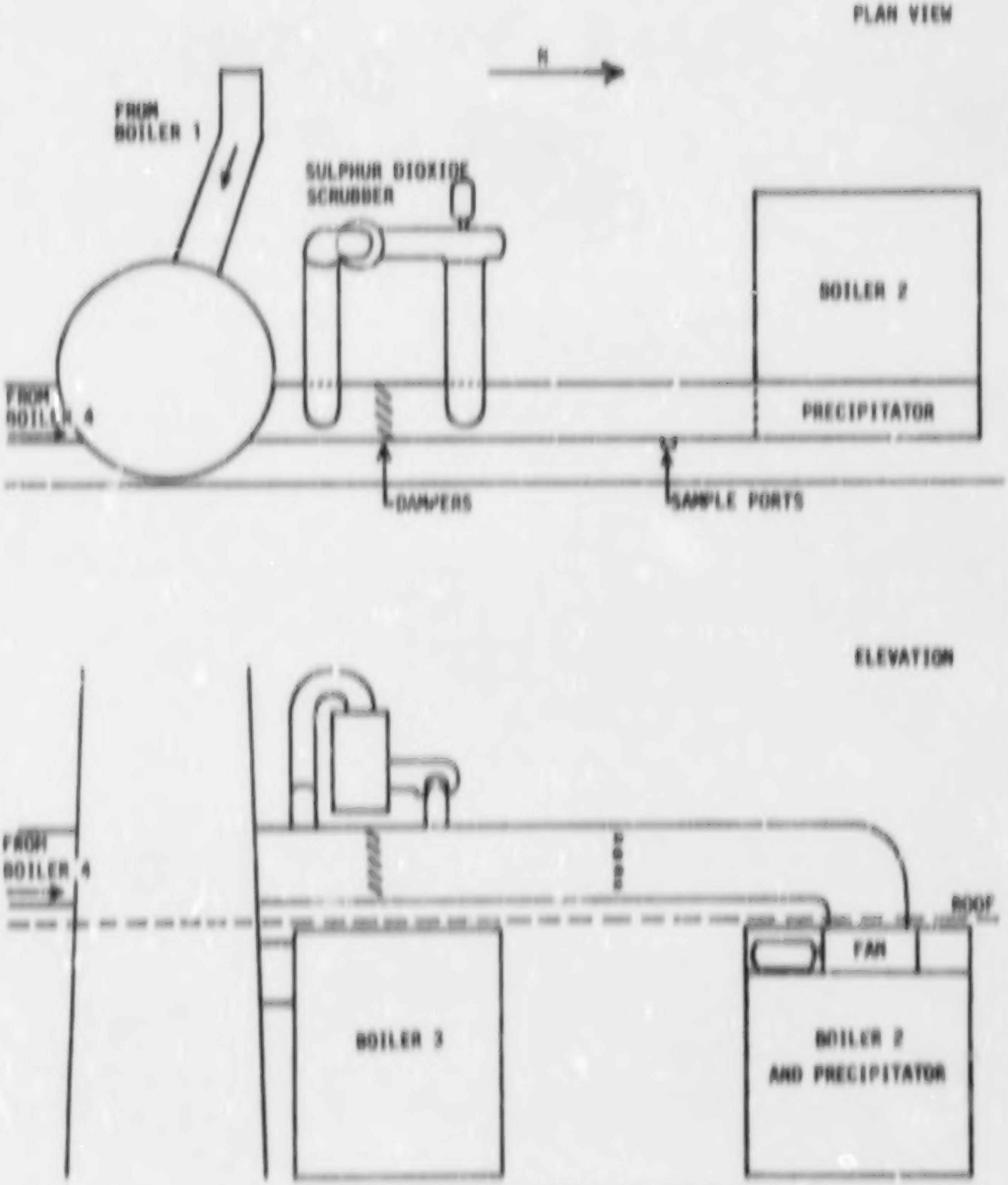
PLAN VIEW
N
FROM BOILER 1
SULPHUR DIOXIDE SCRUBBER
BOILER 2
FROM BOILER 4
PRECIPITATOR
DAMPERS
SAMPLE PORTS
ELEVATION
FROM BOILER 4
ROOF
FAN
BOILER 3
BOILER 2 AND PRECIPITATOR

FIGURE 1 SAMPLING LOCATION FOR BOILER 2

FIGURE 2

OPERATOR POSITIONING SAMPLING UNIT AT TEST LOCATION

FIGURE 3

SUPPORTING STRUCTURE FOR SAMPLING EQUIPMENT

6.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods.

Gas flow rates were calculated using the observed gas temperature, molecular weight, pressure and velocity, and the flow area. The gas velocity was calculated from gas velocity head measurements made with an S-type pitot tube and a magnehelic pressure gauge, using standard method 2.

Moisture contents were determined by passing a measured amount of gas through chilled impingers containing a known volume of deionized water, measuring the increase in volume of the impingers liquid and the increase in weight of silica gel used to finally dry the gas, and calculating the amount of water vapor in the sample from this increase and the measured amount of gas.

The stack gas concentrations of CO_2, oxygen, CO, and nitrogen by difference were measured with a standard Orsat apparatus. This method is shown in Figure 4. These concentrations and the moisture content were used to determine molecular weight of the stack gas.

6.1 PARTICULATE MATTER

Standaru method 5 was used for determining particulate emissions with the exception that the probe and oven were operated at 300-350° °F. Measured stack gas samples were taken under isokinetic conditions. The samples were passed through a cyclone, fiberglass filter, impingers, pump, a meter and an orifice as shown in Figure 5.

The total particulate matter collected in each test was the sum of the filter catch plus material collected ahead of the filter in the sampling train. The amount of filter catch is determined by the difference in the weight of the filter before and after the test, after dessicating. The particulate matter from other portions of the train was determined by rinsing the probe, cyclone and all glassware ahead of the filter with acetone, evaporating to dryness and weighing.

FIGURE 4

OPERATOR DETERMINING STACK GAS COMPOSITION

WITH ORSAT APPARATUS

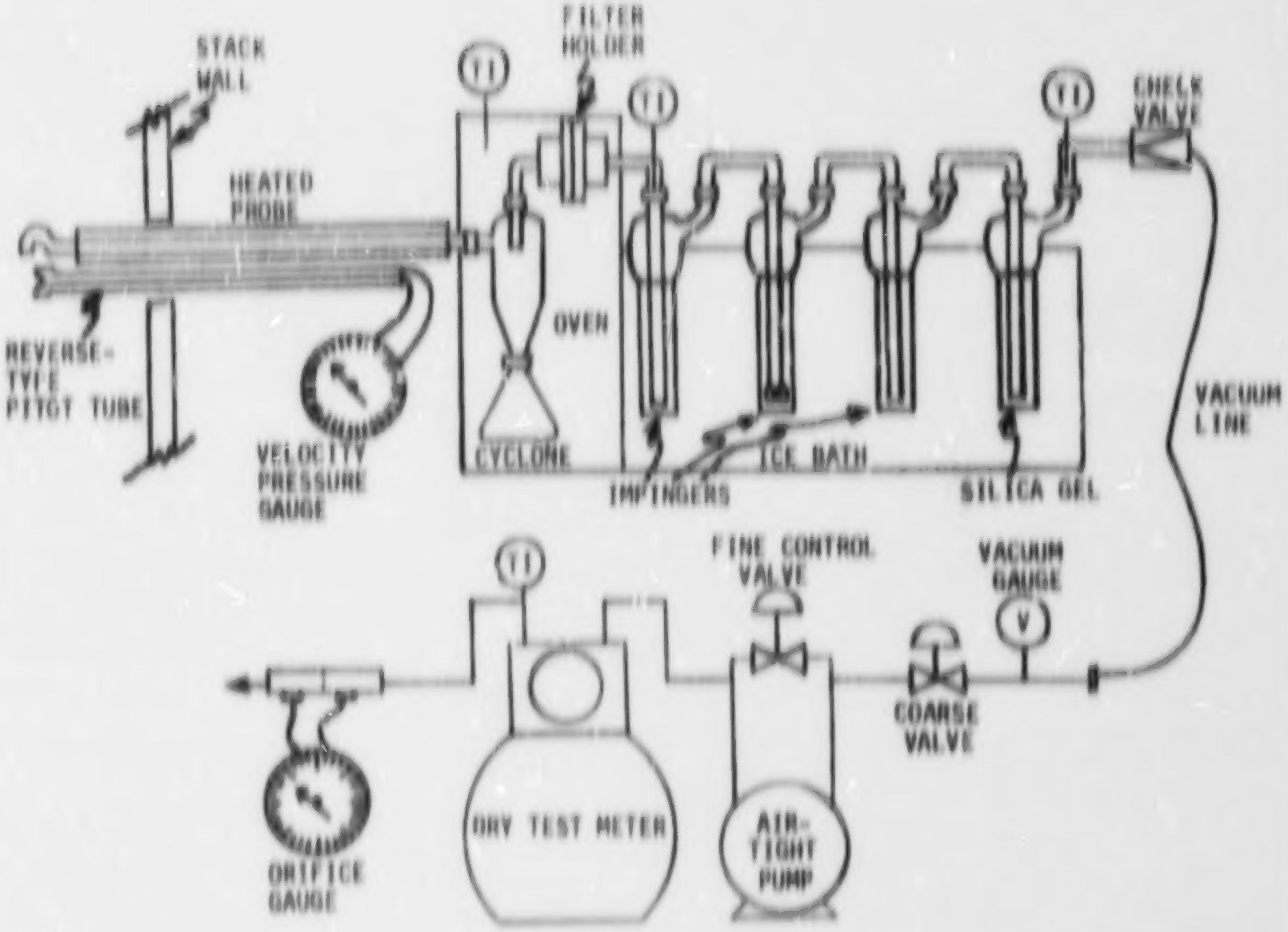
STACK WALL
FILTER HOLDER
TI
TI
TI
TI
CHECK VALVE
HEATED PROBE
REVERSE-TYPE PITOT TUBE
OVEN
VELOCITY PRESSURE GAUGE
CYCLONE
ICE BATH
IMPINGERS
SILICA GEL
VACUUM LINE
FINE CONTROL VALVE
VACUUM GAUGE
V
COARSE VALVE
ORIFICE GAUGE
DRY TEST METER
AIR-TIGHT PUMP

FIGURE 5

PARTICULATE SAMPLING TRAIN

6.2 NITROGEN OXIDE

Using method 7, gas samples were withdrawn from the stack into evacuated 2-liter flasks containing a dilute solution of hydrogen peroxide and sulfuric acid. The hydrogen peroxide oxidizes the lower oxides of nitrogen (except nitrous oxide) to nitric acid. The resultant solution is evaporated to dryness and treated with phenol disulfonic acid reagent and ammonium hydroxide. The yellow trialkali salt of 6-nitro-1-phenol-2, 4-disulfonic acid is formed, which is measured colorimetrically. The field procedure is shown in Figures 6 and 7.

6.3 SULFURIC ACID MIST AND SULFUR DIOXIDE

The Shell method was chosen for this determination due to uncertainties which exist about the validity of the results using method 8.* A gas sample is drawn from the stack using a heated probe and passed through a water-cooled, coil condenser maintained below the dew point of sulfuric acid at 140°-194°F, followed by a fritted glass plate and then passed through a chilled impinger train with two impingers containing an isopropanol and hydrogen peroxide mixture and followed by an impinger containing silica gel for drying. This setup is shown in Figure 8.

The condensed sulfuric acid mist in the coil condenser is water washed from the condenser. The final determination is made by titrating the solution with barium chloride, using a thorin indicator. Isopropanol must be added to the solution to be titrated to improve the rapidity with which the barium sulfate precipitates during titration.

Sulfur dioxide in the gas sample is oxidized to sulfur trioxide in the impingers containing the hydrogen peroxide. Sulfur dioxide is then determined by titrating the hydrogen peroxide solution with barium chloride, using a thorin indicator.

---

*Lisle, E.S. and J.D. Sensenbaugh, "The Determination of Sulfur Trioxide and Acid Dew Point in Flue Gases," Combustion, Jan.1965.

Goksoyr, H. and K. Ross, "The Determination of Sulfur Trioxide in Flue Gases," J. Inst. Fuel, No. 35, 177, (1962)

FIGURE 6

OPERATOR EVACUATING FLASK FOR NITROGEN OXIDES TESTING

FIGURE 7

OPERATOR FILLING EVACUATED FLASK WITH STACK GAS SAMPLE

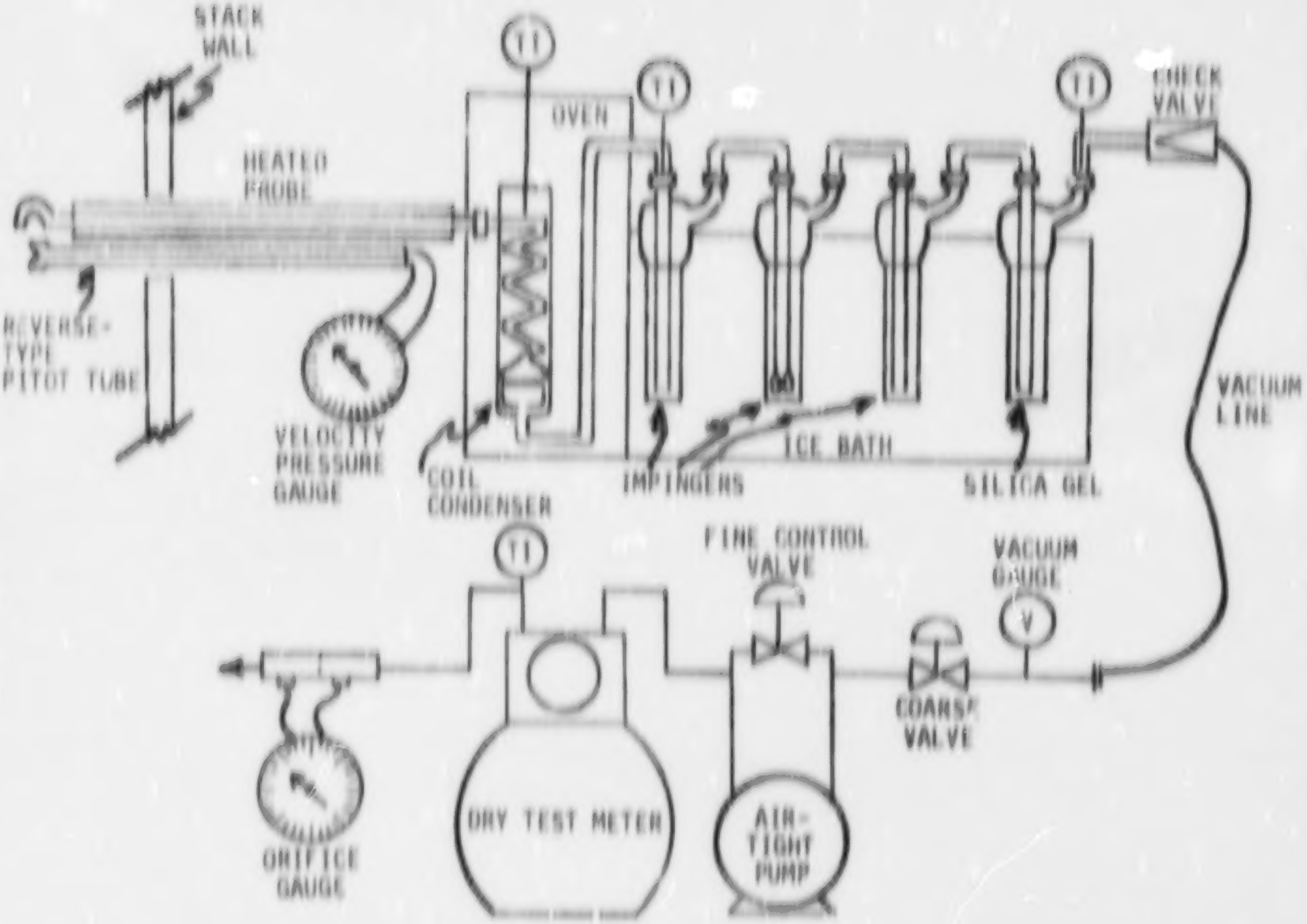
STACK WALL
HEATED PROBE
REVERSE-TYPE PITOT TUBE
VELOCITY PRESSURE GAUGE
TI
OVEN
COIL CONDENSER
TI
IMPINGERS
ICE BATH
TI
SILICA GEL
CHECK VALVE
VACUUM LINE
TI
FINE CONTROL VALVE
VACUUM GAUGE
V
COARSE VALVE
ORIFICE GAUGE
DRY TEST METER
AIR-TIGHT PUMP

FIGURE 8

SULFURIC ACID MIST SAMPLING TRAIN

6.4 PARTICLE SIZE

An Andersen fractionating inertial impactor is used for the determination of particle size in the range of approximately 0.5 to 10.0 microns. The sampling head is placed in the oven after the heated sampling probe and a sample of stack gas is drawn isokinetically through the sampler. The particulate matter is fractionated and collected on the plates inside the sample head and a determination is made by the difference in weight of the plates before and after testing. Results are expressed for particles of unit density. The sampling arrangement is shown in Figure 9. The sampling head assembly is shown in Figure 10.

6.5 HYDROCARBONS

Gas samples were withdrawn from the stack using a vacuum pump to fill Tedlar bags. The composition of the hydrocarbons was determined by gas chromatograph.

FIGURE 9

SAMPLING UNIT WITH ANDERSEN SAMPLER IN OVEN

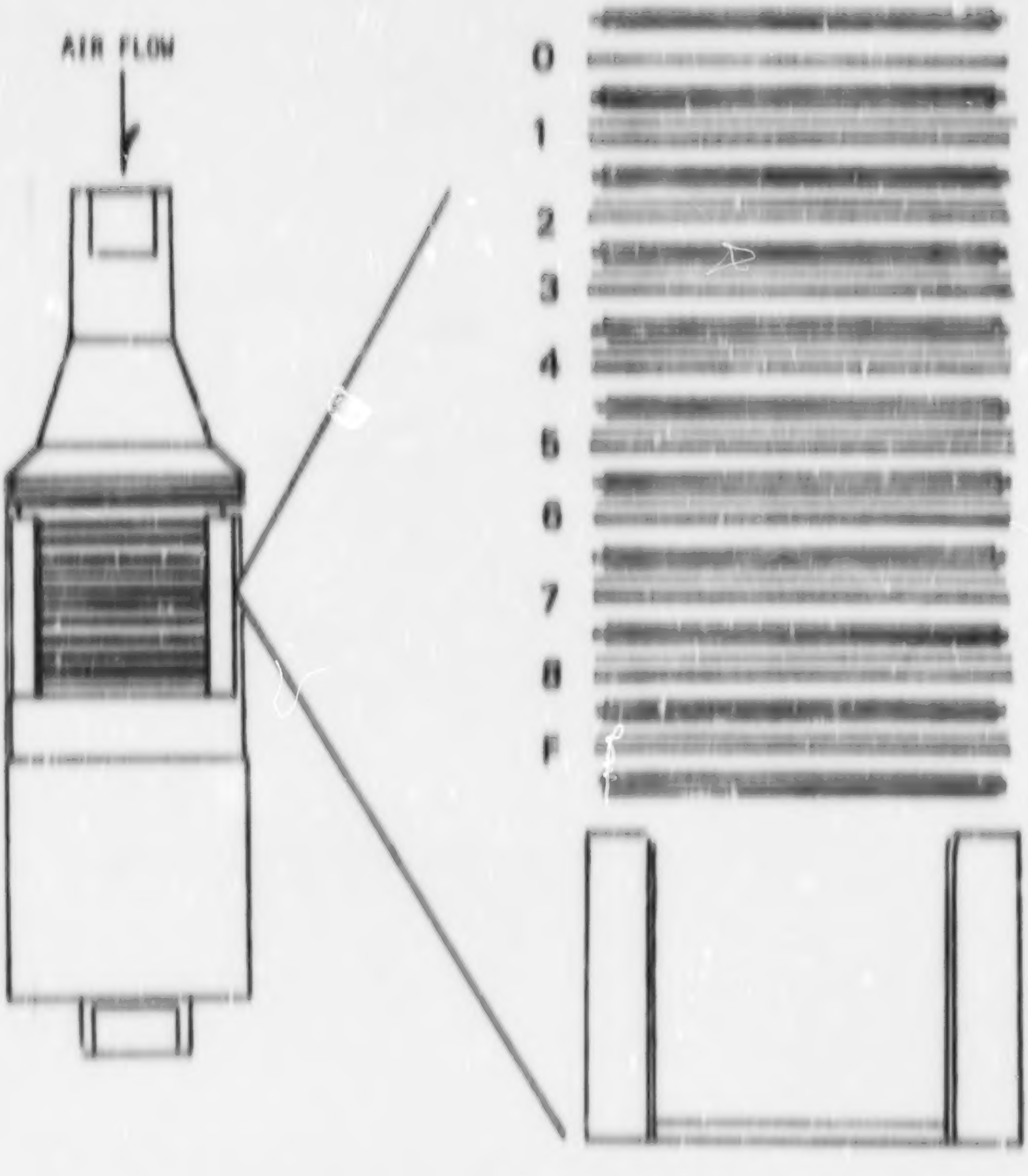
AIR FLOW
0
1
2
3
4
5
6
7
8
F

FIGURE 10
ANDERSEN STACK SAMPLER

7.0 RESULTS

The results obtained from this test are summarized in Table 1. As explained in the following discussion, the pollutant emissions are based on calculated, rather than measured, flow rates. Although these tests were performed for research purposes and not as part of compliance procedures, standard EPA methods were used. Due to the seasonal nature of the local SO_2 regulations the only applicable standard is for particulates. It is of interest to note that this boiler is within the standard: 0.28 lb/10^6 Btu compared to the standard of 0.40 lb/10^6 Btu.

In addition to measuring particulate loadings, a particle size analysis was made using an Andersen impactor. The results are shown in Table 2 and Figure 11.

The results of two samples taken on 8 September for hydrocarbons were:

Carbon Monoxide: 26.80 and 23.04 ppm
Methane: 0.23 and 0.25 ppm
Total Hydrocarbons, as CH_4: 1.31 and 2.30 ppm

The major components of several hydrocarbon samples taken on 8 and 9 September are given in Table 3.

TABLE 1

SUMMARY OF RESULTS

Date	9/8	9/9	9/10		
Stack Flow Rate - SCFM * dry	27,041	26,633	26,633		
% Water Vapor - % Vol.	8.34	7.38			
% CO_2 - Vol % dry	11.16	10.65			
% O_2 - Vol % dry	8.37	9.25			
% Excess air @ sampling point	64.2	75.72			
SO_2 Emissions - lbs/10^6 Btu		5.81	6.14		
NO_x Emissions - lbs/10^6 Btu	0.49	0.48			
H_2SO_4 Mist - lbs/10^6 Btu		0.19	0.16		
Particulates Probe, Cyclone, & Filter Catch					
lbs./hr.	20.41	20.03			
lbs/10^6 Btu	0.25	0.24			
Total Catch					
lbs./hr.					
lbs/10^6 Btu					
% Isokinetic Sampling	113.3	110.8			

*70° F, 29.92" Hg

TABLE 7
PARTICLE SIZE DISTRIBUTION

Test: GM-Andersen #1
Oven Temperature = 300°F

Date: 9/10

Plate	Filter Net (mg)	% Of Total	ECD (Microns)
1	1.1	1.43	16.8
2	1.7	2.21	10.7
3	3.5	4.55	7.1
4	4.7	6.10	4.9
5	4.6	5.97	3.1
6	4.6	5.97	1.6
7	3.5	4.55	0.99
8	5.3	6.88	0.66
Backup Filter	48.0	62.34	<0.66
Total	77.0	100.00	

Test: GM-Andersen #2
Oven Temperature = 370.9°F

Date: 9/11

Plate	Filter Net (mg)	% Of Total	ECD (Microns)
1	1.2	2.39	17.3
2	1.4	2.78	10.9
3	3.3	6.56	7.3
4	5.3	10.54	5.0
5	4.8	9.54	3.2
6	4.5	8.95	1.7
7	3.2	6.36	1.0
8	3.8	7.55	0.68
Backup Filter	22.8	45.33	<0.68
Total	50.3	100.00	

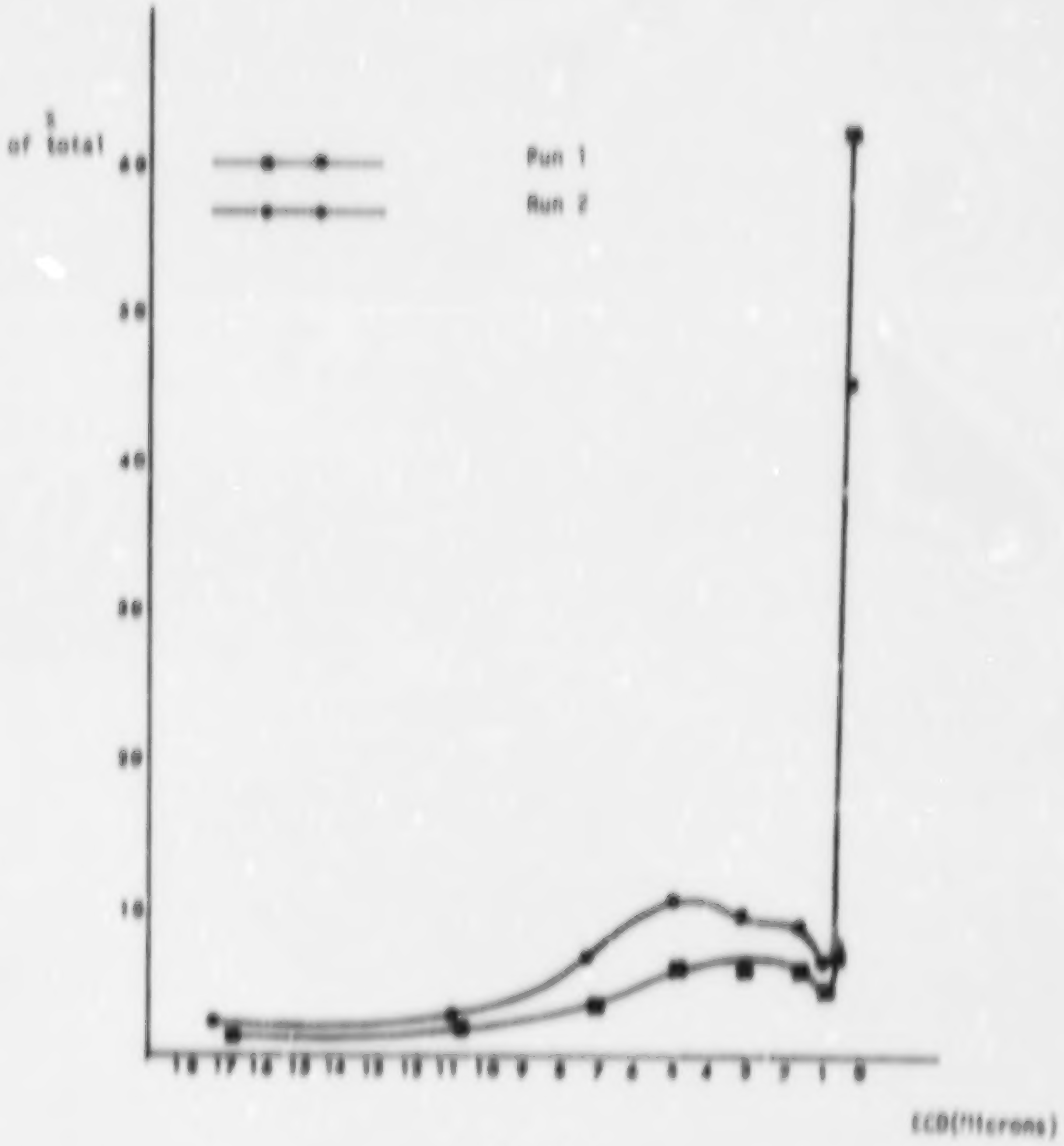

FIGURE 11
PARTICLE SIZE DISTRIBUTION
GENERAL MOTORS
BOILER 2

TABLE 3
HYDROCARBON ANALYSIS
(Concentrations in ppb as Carbon)

Compound	9/8	9/8	9/9	9/9
Ethane-Ethylene	51.7	70.7	68.0	70.3
Acetylene	15.8	29.7	33.7	25.1
Propylene	3.1	7.1		1.7
Propane	29.3	20.2	22.1	33.7
Isobutane	20.3		14.8	25.6
1-Butene & Isobutylene		32.1		29.9
Butane	62.4	72.0	16.9	21.5
Pentane	2.1	9.1	7.4	22.3
Isopentane	4.7	9.2	4.3	21.5
Hexane	52.1	31.7	136.7	95.2
Benzene & 2,4-Dimethyl Pentane	66.3	53.5	14.6	18.7
1-Methylcyclopentane & 2M-C3-Hexane	11.2	37.9		
Toluene	143.4	62.6	76.5	115.3
Ethyl Benzene	58.7	65.2	83.1	100.1
Meta, Para-Xylene	130.3	141.8	182.6	180.4
Ortho-Xylene	29.3	30.4	38.4	40.9

8.0 DISCUSSION

Flow determinations were made in accordance with EPA Standard Method 2, using an S-type pitot tube. This method gives correct results as long as the pitot tube is positioned normally to the flow of gases. This is no problem as long as the flow of gases is laminar and parallel to the walls of the duct. However, if the flow is turbulent or vortex-type, the readings obtained are incorrect, with a positive bias (too high). The existence of a turbulent condition can be ascertained by turning the pitot tube 90° on its axis. A zero reading should then result. If no zero reading is obtained, the results are open to question.

In the duct being tested, the existence of turbulence was evident by the fact that a zero reading was not obtained with a 90° rotation of the probe.

Under conditions when satisfactory flow measurements cannot be obtained, a stoichiometric calculation of flow rates can be made, based on fuel consumption, fuel composition, combustion rate and excess air. As a check on the correctness of the assumption, the mass flow of SO_2 can be calculated based on gas flow and SO_2 concentration on one hand, and fuel consumption and sulfur analysis on the other. The conversion of sulfur in coal to SO_2 is straightforward and occurs with 95% efficiency.

To determine the amount of coal consumed and Btu input, coal scale readings were checked against the actual steam production. This ratio was also compared with a ratio determined by power plant supervision over several previous months. On 10 September the coal scale readings averaged 7314 lbs/hour and the steam flow averaged 66,910 pounds of steam per hour. This gives a ratio of 9.15 pounds of steam per pound of coal. The ratio used by plant supervision is 9.3. Since these two ratios are so close, the ratio of 9.3 determined by plant supervision was the one used for all determinations of coal consumption during the test.

Table 4 shows the comparison of the results obtained by the two methods.

TABLE 4

COMPARISON OF FLOW RATE DETERMINATIONS

Date	FLOW RATE, SCFH		SO_2 (lbs/hr) Based On		
	Measured	Calculated	AP-42*	Calculated Flow	Avg. Measured Flow
9/8	1,622,490	1,403,921			
9/9	1,598,006	1,434,847	478.5	472.0	545.9
9/10		1,396,329	480.0	501.3	578.1

* Compilation of Air Pollutant Emission Factors, EPA Publ. No. AP-42

STOICHIOMETRIC
FLOWRATE CALCULATIONS
BOILER #2

Coal Composition

Moisture 7.71%

Ash 10.895

S 3.465 ÷ 32 = 0.108 x 1 = 0.108

C 62.0 ÷ 12 = 5.167 x 1 = 5.167

H_2 5.0 ÷ 2 = 2.500 x 5 = 1.25

N_2 1.0 ÷ 28 = 0.036

O_2 9.9 ÷ 32 = 0.309 x -1 = -0.309

6.216

@ 70.46% Excess Air 4.380

10.596

N_2 = 3.76 x O_2 = 39.840

Mols Flue Gas = CO_2 + SO_2 + N_2 + EA + N_2 =
5.167 + 0.108 + 0.036 + 4.38 + 39.84 = 49.53 mols/100#

On 9/9 7268.8 lb/hr coal during SO_2 test 49.53 x 386.7 x 72.688 =
1,392,211.5 SCFH

On 9/9 7491.4 lb/hr coal during particulate test 49.53 x 386.7 x 74.914 =
1,434,846.6 SCFH

9/8 7329.9 lb/hr 1,403,921.1 SCFH

9/9 1,434,846.6 SCFH Part.
1,392,211.5 SCFH SO_2

9/10 1,396,329.4 SCFH SO_2
1,363,385.8 SCFH Andersen

APPENDIX A
PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70^{0} F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{CF_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530^{0} R or 70^{0} F

Tm = Meter temperature, 530^{0} R for compensated meter

CFm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = Vl_c\left(\frac{\rho H_2O}{MH_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right)\ \frac{lb.}{454\ gm.} = 0.0474 \times Vl_c$$

Vw = Volume of water vapor at standard conditions, ft^3

Vl_c = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

M H_2O = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - ^{0}R

% Moisture in Stack Gas

$$\% M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\%O_2 \times \frac{32}{100}\right) + \left(\%N_2 \times \frac{28}{100}\right)$$

Molecular weight of stack gas

$$MW_W = \left(\frac{100 - \%M}{100} \times MW_D\right) + \left(\frac{\%M}{100} \times 18\right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{Ts \times \Delta P \text{ avg.}}{Ps \times MW_W}\right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{\text{ft.}}{\text{sec.}} \left(\frac{\text{lb.}}{\text{lb. Mols} - {}^{o}R}\right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, °R

P_s = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Qs = 3600\left(1 - \frac{\%M}{100}\right) V_s \; A\left(\frac{Tstd}{Ts} \; \frac{Ps}{Pstd}\right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Qs' = Q_s \div 60$ = SCFM

Per cent isokinetic sampling

$$I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{V_{m}}{T_{m}}\left(P_{B} + \frac{\Delta H}{13.6}\right)\right] T_{s}}{\theta\ V_{s}\ P_{s}\ A_{n}}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$0.00267 = \frac{\rho H_2O}{M_{H_2O}} \times R \times \frac{lb.}{454\ gm.}$

θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$$C_s = 2.205 \times 10^{-6} \left(\frac{M_n}{Vm_{std}}\right)$$

C_s = particulate emission, lb/scf

2.205×10^{-6} = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_s \times Q_s$ = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% EA = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: Bin 2 - Run 1   Date: 9/6/76

Material collected (mg)

Filter Catch	=	145.1
Dry Catch	=	
Acetone Wash	=	149.4
TOTAL	=	294.5

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \left(\frac{44.74}{1.01}\right)\left(30.16 + \frac{0.46}{13.6}\right) = \underline{44.672}$ SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

$0.0474 \ (85.8 \text{ ml}) = \underline{4.067}$ SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(4.067)}{(44.672) + (4.067)} = \underline{8.34}$ %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(11.16 \times 0.44) + (8.37 \times 0.32) + (80.47 \times 0.28) = \underline{30.12}$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 8.34}{100} \times 30.12\right] + \left[\frac{8.34}{100} \times 18\right] = \underline{29.125}$

PARTICULATE SAMPLING CALCULATIONS

Test: **Blr. 2 - Run 1** Date: **9/8/75**

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times P\ avg}{P_s \times M_w}\right]^{1/2}$

$85.48 \times (0.85) \left[\frac{883.7 \times 0.299}{30.13 \times 29.186}\right]^{1/2} =$ 39.869 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%H}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(8.34)}{100}\right](39869)\ (20.42)\ \frac{530}{(883.7)}\ \frac{(30.13)}{29.92} =$ 1,622,490* SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(294.6)}{(44672)} =$ 1.454×10^{-5} lb/scf

$C_E = C_s \times Q_s = (1.454 \times 10^{-5})\ (1,403,921) =$ 20.41 lb/hr

$C_H = C_E \div H = \frac{(20.41)}{(82.0)} =$ 0.25 lb/10^6 Btu

Isokinetic Variations $I = \frac{1.667\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right] T_s}{\theta\ V_s\ P_s\ A_n}$

$\frac{1.667\left[(0.00267)\ (25.8) + \frac{44.297}{530}\left(30.16 + \frac{0.96}{13.6}\right)\right](883.7)}{(96)\ (34.50)\ (30.13)\ (3.46 \times 10^{-4})} = 112.3\%$

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (8.37)}{(0.266 \times 80.47) - (8.37)} = 64.2$

* Stoichiometric Q_s = 1,403,921.1 SCFH

$V_s = \frac{1,403,921}{1,622,490} \times 39.869 = 34.50$ fps

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 2 - Run 2　　　　Date: 9/9/75

Material collected (mg)

Filter Catch = 120.3
Dry Catch =
Acetone Wash = 148.8

TOTAL = 269.1

Gas Volume　　$Vm_{std} = 0.0334 \left(\frac{V_m}{Cf_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \frac{(42.61)}{(1.01)} \left(30.14 + \frac{0.40}{13.6}\right) = \underline{42.311}$ SCF

Volume of water vapor　　$Vw = 0.0474 \times Vlc$

$0.0474 (71.4 \text{ ml}) = \underline{3.384}$ SCF

% Moisture　　$\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(3.384)}{(42.311) + (3.384)} = \underline{7.38}$ %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(10.68 \times 0.44) + (9.22 \times 0.32) + (80.1 \times 0.28) = \underline{30.07}$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 7.38}{100} \times 30.07\right] + \left[\frac{7.38}{100} \times 18\right] = \underline{29.172}$

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 2 - Run 2 Date: 9/9/95

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times \Delta P\ avg}{P_s \times M_{w}}\right]^{1/2}$

$85.48 \times (0.84) \left[\frac{796.4}{30.11} \times \frac{0.589}{29.192}\right]^{1/2} =$ 39.445 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%H}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \left(\frac{7.38}{100}\right)\right](39.445) \quad (80.42) \quad \frac{530}{(796.4)} \left(\frac{30.11}{29.92}\right) =$ 1,598,008* scfh

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{mstd}}\right)$

$2.205 \times 10^{-6} \left(\frac{269.1}{42.511}\right) =$ 1.396×10^{-5} lb/scf

$C_E = C_s \times Q_s = (1.396 \times 10^{-5}) \quad (1,434,846) =$ 20.03 lb/hr

$C_H = C_E \div H = \left(\frac{20.03}{83.2}\right) =$ 0.24 lb/10^6 Btu

Isokinetic Variations $I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right] T_s}{\theta\ V_s\ P_s\ A_n}$

$1.667 \frac{\left[(0.00267) \quad (69.4) + \frac{42.188}{530}\left(30.11 + \frac{0.90}{13.6}\right)\right](796.4)}{(96)\quad(35.42)\quad(30.13)\quad(3.067 \times 10^{-4})} = 110.8\%$

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

* Stoichiometric $Q_s = 1,434,847$

$\frac{100\ (9.25)}{(0.266\ (81.1)) - (9.25)} = 76.7\%$

$V_s = \frac{1,434,847}{1,598,008} \times 39.445 = 35.42$ fps

STOICIOMETRIC
FLOWRATE CALCULATIONS

Boiler #2

Coal Composition		Mols/100#	Mols O_2 required
Moisture	7.71%		
Ash	10.89%		
S	3.46% ÷ 32 =	0.108 x 1	= 0.108
C	62.0 ÷ 12 =	5.167 x 1	= 5.167
H_2	5.0 ÷ 2 =	2.500 x .5	= 1.25
N_2	1.0 ÷ 28 =	0.036	
O_2	9.9 ÷ 32 =	0.309 x -1	= -0.309
			6.216
@ 70.46% Excess air			4.380
			10.596
N_2 = 3.76 x O_2			= 39.840

Mols Flue Gas = CO_2 + SO_2 + N_2 + EA + N_2 =
5.167 + 0.108 + 0.036 + 4.38 + 39.84 = 49.53 mols/100#

on 9/9 7268.8 lb/hr coal during SO_2 test

49.53 x 386.7 x 72.688 = 1,392,211.5 SCFH

on 9/9 7491.4 lb/hr coal during particulate test

49.53 x 386.7 x 74.914 = 1,434,846.8 SCFH

NO_2 EMISSION DATA

Date 9/8/75

Run No.	1	2	3	4	5	6		
Time	1150	1200	1230	1230	1325	1330		
µg NO_2	865	865	865	815	760	760		
T_i - Initial Flask Temp, °F	90	90	90	90	90	90		
T_f - Final Flask Temp, °F	95	95	95	95	95	95		
V_{fc} - Flask Volume, ml.	2047	2036	2039	2018	2015	2052		
P_i - Initial Flask Pres, "Hg	2.5	2.5	2.5	2.5	2.5	2.5		
P_f - Final Flask Pres, "Hg	30.16	30.16	30.16	30.16	30.16	30.16		
lb/scf NO_2 $\times 10^{-6}$	2.97	2.98	2.98	2.82	2.64	2.60		
lb/10^6 Btu NO_2	0.81	0.81	0.81	0.48	0.48	0.45		

$$V_{sc} = \left(17.71 \frac{°R}{\text{in. Hg}}\right) (V_{fc}) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu\text{g/ml}} \left(\frac{\mu\text{g } NO_2}{V_{sc}}\right) = \text{lb/scf } NO_2$$

NO_x EMISSION DATA

Date 9/9/75

Run No.	1	2	3	4	5	6	7	8
Time	0910	0912	1008	1010	1040	1042	1240	1245
ug NO_2	970	1020	710	760	760	760	760	760
T_i= Initial Flask Temp, °F	90	90	90	90	90	90	90	90
T_f= Final Flask Temp, °F	95	95	95	95	95	95	95	95
V_{fc}= Flask Volume, ml.	2047	2038	2039	2028	2025	2052	2053	2056
P_i= Initial Flask Pres, "Hg	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
P_f= Final Flask Pres, "Hg	30.16	30.16	30.16	30.16	30.16	30.16	30.16	30.16
lb/scf NO_2 x 10^{-8}	3.33	3.52	2.48	2.63	2.64	2.60	2.60	2.60
lb/10^6Btu NO_2	0.57	0.60	0.42	0.45	0.45	0.45	0.45	0.45

$$Vsc = \left(17.71\ \frac{^oR}{in.\ Hg}\right) \quad (Vfc) \quad \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = scf$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5}\ \frac{lb/scf}{ug/ml} \left(\frac{ug\ NO_2}{Vsc}\right) = lb/scf\ NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Date	9/9	9/9	9/9	9/10	9/10	9/10
Run No.	1	2	1 & 2	1	2	1 & 2
V_{mc}-Meter Volume, Ft^3	7.513	6.428	14.436	10.139	8.899	19.238
Vmstd-Meter Volume, Std. Cond.	7.868	6.971	14.836	10.176	8.931	19.107
P_B-Barometric Pressure, "Hg	30.14	30.14	30.14	30.04	30.04	30.04
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1	0.1	0.1	0.1	0.1	0.1
V_t-Vol. of Titrant, ml.	8.4	5.9	27.99	9.8	6.8	39.33
V_{tb}-Vol. of Titrant for Blank, ml.	nil	nil	nil	nil	nil	nil
Vsoln-Vol. of Solution, ml.	100	100	250	100	100	250
V_a-Vol. of Aliquot, Titrated, ml.	10	10	1	10	10	1
lb/scf H_2SO_4 $\times 10^{-6}$	12.00	9.17		10.26	8.22	
lb/10^6 Btu H_2SO_4	0.21	0.16		0.17	0.14	
lb/scf SO_2 $\times 10^{-4}$			3.37		3.04	
lb/10^6 Btu SO_2			5.81		6.14	

$$\text{Vmstd} = 0.0334 \, \frac{(V_m)}{Cf_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

Cf_m = Meter correction factor

$$C_{H_2SO_4} = \frac{\left(1.08 \times 10^{-4} \, \frac{\text{lb-l}}{\text{g-ml}}\right) (V_t - V_{tb}) \; (N) \; \left(\frac{V_{soln}}{V_a}\right)}{V_{mstd}} = \text{lb/scf}$$

N = 0.01 Normal
Barium
Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \, \frac{\text{lb-l}}{\text{g-ml}}\right) (V_t - V_{tb}) \; (N) \; \left(\frac{V_{soln}}{V_a}\right)}{V_{mstd}} = \text{lb/scf}$$

APPENDIX B
FIELD DATA

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Date	9/8	9/9	9/10	
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr				
Boiler Heat Input $\times 10^6$ BTU/hr	82.0	83.8/81.3	81.6/79.6	
Fuel Burning Rate - lb/hr				
Fuel Heating Value - BTU/lb	11187			
Fuel Sulfur Content - %	3.468			
Fuel Ash Content - %	10.898			
Fuel Moisture Content %	7.71			

9/8
use 82.0 $\times 10^6$ Btu/hr

9/9 for particulates & NO_x
9:00 AM 70 $\times 10^3$ lb/hr steam
9:30 70
10:00 70
10:30 68
11:00 70
11:30 70
69.67 $\times 10^3$ lb/hr
÷ 9.3 = 7491.4 lb/hr coal
× 11187 = 83.8 $\times 10^6$ Btu/hr

9/9 for SO_2 & SO_3
11:30 70 $\times 10^3$
12:00 67
12:30 70
1:00 71
1:30 69
2:00 63
2:30 63
67.6 $\times 10^3$ lb/hr
÷ 9.3 = 7268.8 lb/hr coal
× 11187 = 81.3 $\times 10^6$ Btu/hr [illegible]

9/10 for SO_2 & SO_3
9:00 67
9:30 67
10:00 70
10:30 68
11:00 67
67.8 $\times 10^3$ lb/hr ÷ 7290.3 lb/hr coal × 81.6 $\times 10^6$ [illegible]

11:30 67
12:00 67
12:30 67
1:00 62
1:30 64
2:00 64
66.2 $\times 10^3$ ÷ 7118.3 lb/hr coal × 79.6 $\times 10^6$ Btu/hr

for Andersens

ORSAT FIELD DATA

Location General Motors - St. Louis Comments:

Date 9/8 , 9/9 , 9/10

Time

Operator Klein

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
9/8 1030	10.7	8.7	0
1105	11.8	8.2	0
1315	11.0	8.2	0
9/9 0900	10.5	8.9	0
0950	10.8	9.6	0
9/10 0830	10.2	9.9	0
1025	11.4	9.2	0
1315	11.2	8.8	0

Plant GM[illegible]

Run No. 1

Location #2 [illegible]

Date 9/8/75

Operator

Sample Box No.

Meter Box No.

Meter ΔH@ 1.682

C Factor

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 85

Bar. Press. "Hg 30.16

Assumed Moisture % 10

Heater Box Setting °F 4 (335°)

Probe Tip Dia., In. 3/8 → [illegible]

Probe Length [illegible]

Probe Heater Setting 5 (335°)

Avg. ΔP ___ Avg. ΔH ___

Point	Clock	Dry Gas Meter, CF	Pitot in H2O ΔP	Orifice ΔH in H2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:37	1218.450	0.12	1.45	1.45	160	80		310	340	-0.4	390
1-2	10:40	1221	0.21	1.4	1.4	210	67		325	340		420
1-3	[illegible]	1225	0.25	2.48	2.48	190	70	4.0	290	300		440
1-4	[illegible]	[illegible]	[illegible]	2.55	2.55	220	68		315	330		490
1-5	[illegible]	1227.5	[illegible]	2.55	2.55	245	65		330	315		490
1-6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	260	64		350	320		435
1-7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	270	68		350	340		440
1-8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	275	67		350	310		440
[illegible]	[illegible]											
2-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	205	80		340	375		[illegible]
2-2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	240	75		330	380		420
2-3	[illegible]	1236.3	[illegible]	[illegible]	[illegible]	245	72		335	325		430
2-4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	260	72		325	335		430
2-5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	250	72		340	345		430
2-6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	255	75		340	310		440
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	260	72		340	345		450
2-8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	265	70	6.5	350	330		435

#1 Run

Point	Clock Time	Dry Gas Meter CF	Pitot In. H2O ΔP	Orifice ΔH In. H2O		Impinger °F Temp		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
3-1	12:23	1245.20	0.25	0.24	0.24	195	85		335	270		360
3-2	12:26	1247	0.25	0.24	0.24	270	73		335	315		420
3-3	12:29	1248.1	0.1	0.3	0.3	270	70		335	325		420
3-4	12:32	1247.4	0.1	0.3	0.3	275	70		345	335		435
3-5	12:35	1248.5	0.16	0.2	0.2	270	70		340	340		425
3-6	12:38	1249.6	0.06	0.2	0.2							
3-7	12:41	1250.1	0.1	0.4	0.4	270	70		335	325		440
3-8	12:44	1252.4	0.55	0.75	0.75	270	67		340	340		450
end	12:47	1252.4	0.55									
4-1	1:30	1253.40	0.4	0.35	0.35	200	90		340	315		415
4-2	1:33	1255.2	0.32	0.45	0.45	270	70		335	325		420
4-3	1:07	1256.7	0.32	0.45	0.45							420
4-4	1:10	1257.9	0.45	0.4	0.4	265	70		340	345		430
4-5	1:13	1258.1	0.25	0.34	0.35	270	70		345	350		425
4-6	1:16	1260.5	0.3	0.40	0.40	275	70		350	340		430
4-7	1:19	1262	0.25	0.35	0.35							
4-8	1:22	1263.1	0.24	0.32	0.35	280	72		350	340		425
end	1:25	1264.25										

Comments: After port 3, checked pitot against standard pitot in stack. $\Delta P_s = 0.21$ $\Delta P_c = 0.46$

$$\left[\frac{\Delta P_s}{\Delta P_c}\right]^{1/2} = 0.67$$

Plant G.M.A.D.

Run No. 2

Location #2 [illegible]

Date 9/4/75

Operator

Sample Box No.

Meter Box No.

Meter ΔH@ 1.846

C Factor 0.52

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 85

Bar. Press. "Hg 30.14

Assumed Moisture % 2.5

Heater Box Setting °F

Probe Tip Dia., In. 1/4

Probe Length 5 ft. & [illegible]

Probe Heater Setting

Avg. ΔP ____ Avg. ΔH ____

Point	Clock	Dry Gas Meter, CF	Pitot in H₂O ΔP	Orifice ΔH in H₂O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. H₂O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	9:06	1014.270	0.3	0.28	0.3	90	72	3.5	325	300	-0.4	430
1-2	9:09	1016.5	0.24	0.22	0.22	200	65		330	310		430
1-3	9:12	1016.75	0.25	0.25	0.25	315	65		335	315		430
1-4	9:15	[illegible]	0.24	0.22	0.24	[illegible]	65		335	315		440
1-5	9:18	[illegible]	0.24	0.22	0.24	330	64		340	315		440
1-6	9:21	1020.7	0.3	0.4	0.4	340	68		345	325		440
1-7	9:24	[illegible]	0.45	0.6	0.6	340	65	6.0	345	330		440
1-8	9:27	[illegible]	0.5	0.7	0.7	350	65		350	330		440
[illegible]	9:30	1025.55										
2-1	9:42	[illegible]	0.25	0.28	0.25	320	75		350	315		330
2-2	9:45	1027.7	0.2	0.22	0.2	350	69		355	330		430
2-3	9:48	1028	0.15	0.2	0.2	355	76		350	335		440
2-4	9:51	1029	0.1	0.15	0.15	355	72		350	335		440
2-5	9:54	1030.1	0.1	0.15	0.15	355	76		350	335		442
2-6	9:57	1031.0	0.15	0.2	0.2	355	72		345	340		440
2-7	[illegible]	[illegible]	0.25	0.35	0.35	350	76		345	350		440
2-8	[illegible]	[illegible]	0.55	0.9	0.9	355	67		350	350		440

GMED # 2 Run

Point	Clock Time	Dry Gas Meter Ft³	Pitot In H2O ΔP	Orifice ΔH In H2O		Impinger °F Temp		Pump Vacuum In Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
3-1	10:18	1285.10	0.3	0.4	0.4	150	75		240	300		430
-2	21	1286.6	0.2	0.3	0.3	250	68		240	320		440
-3	24	1287.7	0.16	0.22	0.25	255	66		240	330		440
-4	27	1288.8	0.12	0.15	0.15	250	64		240	340		440
-5	30	1289.7	0.1	0.14	0.15	250	65		240	340		440
-6	33	1290.7	0.14	0.16	0.16	250	65		240	355		440
-7	36	1291.9	0.25	0.35	0.36	250	67		245	345		440
-8	39	1292.1	0.6	0.82	0.83	260	63		245	320		440
off	42	1294.35										
4-1	10:53	1294.355	0.4	0.55	0.55				245	350		430
-2	56	1296.1	0.45	0.6	0.6	260	63		245	350		440
-3	59	1297.7	0.4	0.55	0.55	270	63		250	350		445
-4	11 02	1299.4	0.3	0.42	0.42	275	65	5.0	245	330		450
-5	05	1300.8	0.3	0.42	0.42	270	65		250	340		450
-6	08	1302.2	0.35	0.5	0.5	275	65		245	335		450
-7	11	1302.7	0.4	0.55	0.55	275	65		245	330		450
-8	14	1305.3	0.5	0.7	0.7	275	65		250	330		450
off	11:17	1306.80										

Comments

PARTICULATE CLEANUP SHEET

Date: 9/8/76 Plant: GMAD

Run Number: 1 Location Of Sample Port: #2 Boiler

Operator: Barometric Pressure: 30.16

Sample Box No. Ambient Temperature 88

Impinger H2O

Volume After Sampling 272 ml

Impinger Prefilled With 200 ml

Volume Collected 72.0 ml

Silica Gel

Weight After 619.0 g

Weight Before 606.2 g

Moisture Weight 12.8 g Moisture Total 84.8 g

Dry Probe and Cyclone Catch:

Container No.

Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No.

Extra No. Weight Results 0.1484 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.

Filter Particulate Weight 0.1461 g

Total Particulate Weight 0.2945 g

% Moisture By Volume

PARTICULATE CLEANUP SHEET

Date: 9/9/78
Plant: GMAD
Run Number: 2
Location Of Sample Port: #4 Boiler
Operator:
Barometric Pressure: 30.14
Sample Box No.
Ambient Temperature 85

Impinger H2O

Volume After Sampling 260 ml
Impinger Prefilled With 200 ml
Volume Collected 60 ml

Silica Gel

Weight After 5284 g
Weight Before 5190 g
Moisture Weight 94 g Moisture Total 154 g

Dry Probe and Cyclone Catch:
Container No.
Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:
Container No.
Extra No. Weight Results 0.1368 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.

Filter Particulate Weight 0.1303 g

Total Particulate Weight 0.2671 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 9/8/76

Plant General Motors

Sample Collected By Klein

Field Data

Clock Time	1150	1200	1230	1250	1325	1330		
Flask number	1	2	3	4	5	6		
Volume of flask (ml)*	2047	2018	2037	2029	2015	2016		
Pressure before sampling in. Hg.	1.1	1.5	2.3	2.3	2.1	2.1		
Pressure after sampling, in. Hg.	30.16	30.16	30.16	30.16	30.16	30.16		
Flask temperature, °F	90	90	90	90	90	90		

* Flask + valve - 25 ml. for absorbing solution

OXIDES OF NITROGEN FIELD DATA

Date 9/9/75

Plant General Motors

Sample Collected By Klein

Field Data

Clock Time	0910	0912	1008	1010	1040	1042	1240	1242
Flask number	1	2	3	4	5	6	7	8
Volume of flask (ml)[a]	2047	2038	2029	2020	2026	2012	2012	2016
Pressure before sampling in. Hg	2.5	2.5	2.5	2.1	2.5	2.6	2.5	2.5
Pressure after sampling, in. Hg.	30.14	30.14	30.14	30.14	30.14	30.14	30.14	30.14
Flask temperature, °F	90	90	90	90	90	90	90	90

[a] Flask + valve - 25 ml. for absorbing solution

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 9/9/75

Plant GMAD

Location #1 Boiler

Bar. Pressure 30.14 "Hg

Comments: Point 2-6

Ambient Temp 90 °F

Run No 1

Power Stat Setting

Filter Used: Yes ___ No ___

Operator

Clock Time	Meter (Ft.³)	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger	
							In	Out
1:00	1327.098	0.16	0.1	450	325		100	85
1:05	1328.8	0.16	0.1	450	365	160	120	75
1:10	1329.6	0.15	0.1	446	340	170	145	75
1:15	1330.9	0.15	0.1	440	350	175	140	76
1:20	1333.2	0.12	0.1	445	385	174	135	77
1:25	1336.5	0.15	0.1	440	315	170	130	80
1:30	1339.630							

Comments: 9.528 ft³

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 9/9/75

Plant GMAD Location #2 Boiler

Bar. Pressure 30.14 "Hg Comments: Point 2-6

Ambient Temp 90 °F

Run No 2

Power Stat Setting ______

Filter Used: Yes ______ No ____

Operator ______

Clock Time	Meter (Ft.³)	Pitot in. H2O ΔP	Orifice in H2O ΔH	Temperatures °F Stack	Probe	Coil	Impinger In	Out
1:40	1334.630	0.15	0.1	440	300	145	110	72
1:45	1336.0	0.15	0.1	440	340	158	126	74
1:50	1337.0	0.12	0.1	440	325	164	140	74
1:55	1338.2	0.12	0.1	430	305	170	138	75
2:00	1339.3	0.12	0.1	430	320	170	130	76
2:05	1340.5	0.15	0.1	425	310	165	125	77
2:10	1341.622							

Comments: 6.992 ft³

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 9/10/75

Plant GMAD Location #2 Boiler

Bar. Pressure 30.04 "Hg Comments:

Ambient Temp 80 °F

Run No 1

Power Stat Setting

Filter Used: Yes No

Operator

Clock Time	Meter (Ft.^{3})	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F Stack	Probe	Coil	Impinger In	Out
9:13	1341.630	0.18	0.1	430	270	175	130	84
9:18	1342.9	0.2	0.1	430	305	170	150	77
9:28	1345.	0.2	0.1	430	300	165	125	79
9:38	1347.5	0.19	0.1	435	315		120	80
9:48	1349.8	0.2	0.1	430	330	160	118	81
9:58	1352.012							

Comments: 10.382 ft^3

Coal Counter 9:15 966 511 1 count = 2lb

10:05 966 562

12:09 966 665

2:06 966 703

192 × 2000 = [illegible]

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 9/10/75

Plant GMAD

Location #2 Boiler

Bar. Pressure 30.04 "Hg

Comments:

Ambient Temp 85 °F

Run No 2

Power Stat Setting

Filter Used: Yes ____ No ____

Operator

Clock Time	Meter (Ft.^{3})	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger In	Impinger Out
10:10	1352.072	0.2	0.1	440	280	140	140	88
10:15	1354.15	0.19	0.1	440	290		160	85
10:25	1355.25	0.18	0.1	440	330	166	150	83
10:35	1357.2	0.2	0.1	440	355		130	87
10:45	1359.1	0.2	0.1	440	315	160	125	88
10:55	1361.060	0.2						

Comments: 8.988 ft³

Plant GMAD

Run No. 1-[illegible]

Location [illegible]

Date [illegible]

Operator ______

Sample Box No. ______

Meter Box No. ______

Meter ΔH@ 1.822

C Factor ______

PARTICULATE FIELD DATA
VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Filters in Oven

Ambient Temp °F 90

Bar. Press. "Hg 30.04

Assumed Moisture % 8.5

Heater Box Setting °F ______

Probe Tip Dia., In. 1/4

Probe Length 5 ft. [illegible]

Probe Heater Setting ______

Avg. ΔP ____ Avg. ΔH ______

Point	Clock	Dry Gas Meter, CF	Pitot in H₂O ΔP	Orifice ΔH in H₂O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. [illegible]	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-7	11:45	1361.240	0.29	2.4	2.4	190	80	5.5	300	290	-0.4	430
	11:48	1362.38	0.29	2.4	2.4	210	71		301	295		425
	11:51	1363.73	0.29	2.4	2.4	228	70		298	301		430
	11:54	1365.05	0.3	2.4	2.4	226	70		302	305		430
	11:57	1366.45	0.3	2.4	2.4	225	70		305	310		435
	12:00	1367.75	0.3	2.4	2.4	224	71		291	320		435
	12:03	1369.10	0.3	2.4	2.4	226	71	6.0	300	305		415
	12:06	[illegible]	0.27	2.4	2.4	225	71		295	315		425
	12:09	[illegible]	0.26	2.26	2.4	255	71		304	325		430
	12:12	[illegible]	0.29	2.4	2.4	252	71		300	315		430
	12:15	[illegible]										

Plant GMAD

Run No. 2-Andersen

Location #2 Bower

Date 9/10/75

Operator

Sample Box No.

Meter Box No.

Meter ΔH@

C Factor

PARTICULATE FIELD DATA

VERY IMPORTANT - FILL IN ALL BLANKS

Read and record at the start of each test point.

Filters in Oven

Ambient Temp °F 90

Bar. Press. "Hg 30.04

Assumed Moisture % 2.5

Heater Box Setting °F 7

Probe Tip Dia., In. 1/4

Probe Length 5 ft glass

Probe Heater Setting 7

Avg. ΔP ____ Avg. ΔH ____

Point	Clock	Dry Gas Meter, CF	Pitot in H₂O ΔP	Orifice ΔH in H₂O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. H₂O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-7	1:12	1374.288	0.29	0.4	0.4	175	93	5.5	360	310	-0.4	430
	1:15	1375.6	.22	0.32	0.4	255	75		365	325		430
	1:18	1377.0	0.23	0.33	0.4	265	74		365	330		430
	1:21	1378.19	0.29	0.4	0.4	276	73		363	310		430
	1:24	1379.7	0.29	0.33	0.4	280	73	6.0	367	320		430
	1:27	1380.8	0.29	0.4	0.4	285	75		364	320		430
	1:30	1382.3	0.28	0.37	0.4	295	76		375	325		430
	1:33	1383.6	0.24	0.33	0.4	295	76		375	330		430
	1:36	1385.0	0.28	0.38	0.4	300	75		380	330		430
	1:39	1386.1	0.27	0.37	0.4	310	78		390	345		430
	1:42	1387.628										

PARTICULATE CLEANUP SHEET

Date: 9/10/75 Plant: GMAD

Run Number: Andersen 1 & 2 Location Of Sample Port: #6 Boiler

Operator: Barometric Pressure: 30.04

Sample Box No. Ambient Temperature

Impinger H2O

Volume After Sampling 241 ml

Impinger Prefilled With 200 ml

Volume Collected 41 ml

Silica Gel

Weight After 815.4 g

Weight Before 806.0 g

Moisture Weight 9.4 g Moisture Total 50.4 g

Dry Probe and Cyclone Catch:

Container No.

Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No.

Extra No. Weight Results 0.0401g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
Backup		Filters 4	
Filters			
Backup #			

Filter Particulate
Weight 0.1278 g

Total Particulate
Weight 0.1679 g

% Moisture By Volume

Particle Size Determination

Test: 1 Date: 9/10/78

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1489	0.1500		1.1		1.43	1.43	16.8
2	0.1437	0.1454		1.7		2.21	3.64	10.7
3	0.1470	0.1505		3.5		4.55	8.19	7.1
4	0.1416	0.1463		4.7		6.10	14.29	4.9
5	0.1812	0.1858		4.6		5.97	20.26	3.1
6	0.1444	0.1490		4.6		5.97	26.23	1.6
7	0.1492	0.1527		3.5		4.55	30.78	0.99
8	0.1437	0.1490		5.3		6.88	37.66	0.66
Back Up Filter	0.2145	0.2625		48.0		62.34	100.0	<0.66
			Total	77.0		100.0		

Test: 2 Date: 9/10/78

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1485	0.1497		1.2		2.39	2.39	17.3
2	0.1410	0.1424		1.4		2.78	5.17	10.9
3	0.1548	0.1580		3.2		6.36	11.53	7.3
4	0.1400	0.1452		5.2		10.34	21.87	5.0
5	0.1823	0.1871		4.8		9.54	31.41	3.2
6	0.1461	0.1506		4.5		8.95	40.36	1.7
7	0.1468	0.1500		3.2		6.36	46.72	1.0
8	0.1488	0.1526		3.8		7.55	54.27	0.68
Back Up Filter	0.2130	0.2360		23.0		45.73	100.0	<0.68
			Total	50.3		100.0		

SOURCE TEST REPORT
AMOCO OIL REFINERY
WOOD RIVER, ILLINOIS
BOILER NO. 6 - POWERHOUSE
AND
CATALYTIC CRACKER REGENERATOR

TESTED BY: ROCKWELL INTERNATIONAL
R.W. Griscom
D.C. Klein
F.E. Littman

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1.0 SUMMARY

In conjunction with the RAPS project, a limited stack testing program is being conducted. This report details the results obtained on boiler no. 6 in the powerhouse and the stack for the catalytic cracker regenerator at the Amoco Oil Refinery in Wood River, Illinois.

The stack testing included the following pollutants: sulfur dioxide (SO_2), particulates, nitrogen oxides (NO_x), sulfuric acid mist (H_2SO_4), and hydrocarbons. Orsat analysis is for carbon dioxide (CO_2), carbon monoxide (CO), and oxygen (O_2) were also performed. Results of these tests are included in this report. The tests on boiler no. 6 were not conducted to ascertain compliance with Illinois standards. Amoco Oil may choose to use the test on the catalytic cracker regenerator for demonstrating compliance since the precipitator on this unit was just recently installed. Thus, it is of interest to note that this unit is in compliance with the regulations for particulates, SO_2 and CO.

The test on the catalytic cracker regenerator was witnessed by E. Sullivan, R. Yoder, and J.C. Rhodes of Amoco and Dr. John Reed of Illinois EPA Permit Section and Mr. Fred Smith of Illinois EPA Testing Section.

We acknowledge and appreciate the excellent cooperation we obtained from the management and engineering personnel of the Amoco Oil Refinery.

2.0 INTRODUCTION

The current stack testing program is being conducted in conjunction with the emission inventory work for the St. Louis RAPS project. The emission inventory is being compiled using published emission factors. The stack testing is being conducted to evaluate the emission factors and to gather information for additional emission factors.

This stack test was conducted at the Amoco Oil Refinery in Wood River, Illinois. Testing was performed on the No. 6 boiler at the powerhouse on 4, 5 and 6 November 1975 and on the Catalytic Cracker Regenerator on 12 and 17 November 1975.

Boiler No. 6 is an oil and gas fired, 200,000 pounds per hour steam generating unit. There are no emission controls on this unit. This boiler was sampled for total particulates, particle size, nitrogen oxides, sulfur dioxide, sulfuric acid mist, carbon dioxide, oxygen and hydrocarbons.

The Catalytic Cracker Regenerator was recently equipped with an electrostatic precipitator. This stack test may be used as a compliance test on the newly installed precipitator. This unit was sampled for total particulates, nitrogen oxides, sulfur dioxide, sulfuric acid mist, carbon dioxide, oxygen, carbon monoxide and hydrocarbons.

3.0 PROCESS DESCRIPTION

Boiler no. 5 was built in 1956 by Babcock and Wilcox. The boiler is fired with a combination of plant oil and gas streams. Steam pressure is approximately 600 psi. This boiler "swings" with the plant, that is, it picks up upsets or changes in plant operation or demands. The capacity of this boiler is rated at 200,000 pounds of steam per hour. For environmental concerns this boiler has been derated to less than 250 x 10^6 Btu/hr input.

There are no stack emission controls on this boiler. Boiler no. 5 is an induced draft unit and exhausts through a masonary lined, steel stack which is 159 feet tall and 6.5 feet inside diameter.

The Catalytic Cracker Regenerator has had an electrostatic precipitator installed during 1975. This precipitator was started up at the end of October 1975. There is also a waste boiler being installed ahead of the precipitator but this was not in operation at the time of testing. The stack is of steel construction and is 171 feet tall and 8 feet inside diameter.

4.0 PROCESS OPERATION

Boiler no. 6 was tested on 4,5 and 6 November 1975. During the testing the boiler load remained fairly constant even though it was picking up any changes in plant operation. This boiler was fired on refinery gas, fuel oil, and "slop" oil during testing. Since there are no individual meters there was no way of knowing how much of each fuel was being burned. There were no visible changes in emissions during testing.

The Catalytic Cracker Regenerator was tested on 12 and 17 November 1975. Since the startup of the precipitator during late October there had been some problems with the precipitator. During testing, the conveyors that remove the collected material from the precipitator were not operating. This did not seem to interfere with testing. On 17 November, however, there was a short in one of several compartments of the precipitator and the precipitator was only kept in operation for our particulate test. The tests for sulfur dioxide, sulfuric acid mist, and nitrogen oxides were run with the precipitator by-passed. Visible emissions at this time increased significantly.

Since the waste heat boiler was still being installed during testing, water was being sprayed into the gas stream to drop the gas temperature from 1,000°F to 600°F to prevent damage to the precipitator. This condition raised the flue gas moisture content to approximately 29%.

5.0 SOURCE TEST DESCRIPTION

Boiler no. 6 was tested in the stack. The sampling location and testing arrangement are shown in Figures 1 and 2. Figure 2 illustrates how the sampling equipment was somewhat obstructed. In order to make a complete traverse at this sample port, a short 5 foot probe was used for the near points and a longer 10 foot probe was used for the far sample points..

The stack is 8.5 foot inside diameter. The sampling location was approximately 36 feet from the stack inlet which is perpendicular to the stack. This means that the sample ports are 4 diameters from the inlet. In accordance with EPA Standard Method 1, 36 sampling points were chosen, 18 on a traverse. A 3-inch pipe coupling, pipe nipple, and reducing flange were used to attach to an existing standard 4-inch flange on the sample ports.

The Catalytic Cracker Regenerator was tested in the stack after the precipitator. Figure 3 illustrates the regenerator to the right followed by the precipitator in the center and the stack to the left. Figure 4 shows the stack and sampling platform and the crane used to hoist the sampling equipment up to the platform. The testing arrangement is shown in Figures 5 and 6.

The stack is 8 foot inside diameter and the sampling location is approximately 80 feet from the stack inlet. In accordance with EPA Standard Method 1, since the sampling location was more than 8 diameters from the inlet, 12 sample points were chosen, 6 on a diameter. A 3-inch pipe coupling, pipe reducer, and a 4-inch flange were used to attach to the existing 4-inch flanges on the sample ports.

FIGURE 1

SAMPLING EQUIPMENT SET UP AT SE PORT - BOILER NO. 6

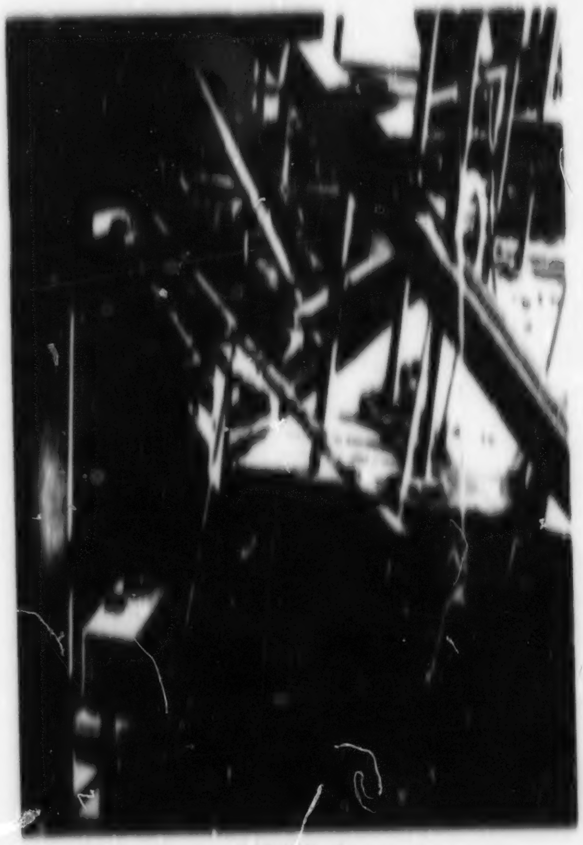

FIGURE 2

SAMPLING EQUIPMENT SET UP AT SW PORT - BOILER NO. 6

FIGURE 3

CATALYTIC CRACKER REGENERATOR, PRECIPITATOR, AND STACK

FIGURE 4

STACK, SAMPLING PLATFORM, AND CRANE FOR HOISTING

FIGURE 5

SAMPLING EQUIPMENT SUPPORT

FIGURE 6

SAMPLING EQUIPMENT SET UP FOR TESTING

6.0 SAMPLING AND ANALYTICAL PROCEDURES

All testing was performed with sampling equipment from Joy Manufacturing, designed for isokinetic sampling to enable testing by EPA standard methods.

Gas flow rates were calculated using the observed gas temperature, molecular weight, pressure and velocity, and the flow area. The gas velocity was calculated from gas velocity head measurements made with an S-type pitot tube and a magnehelic pressure gauge, using standard method 2.

Moisture contents were determined by passing a measured amount of gas through chilled impingers containing a known volume of deionized water, measuring the increase in volume of the impingers liquid and the increase in weight of silica gel used to finally dry the gas, and calculating the amount of water vapor in the sample from the increase and the measured amount of gas.

The stack gas concentrations of carbon dioxide, oxygen, carbon monoxide, and nitrogen by difference were measured with a standard Orsat apparatus. These concentrations and the moisture content were used to determine molecular weight of the stack gas.

6.1 PARTICULATE MATTER

Standard method 5 was used for determining particulate emissions with the exception that the probe and oven were operated at 300-350 °F. Measured stack gas samples were taken under isokinetic conditions. The samples were passed through a cyclone, fiberglass filter, impingers, pump, a meter and an orifice as shown in Figure 7.

The total particulate matter collected in each test was the sum of the filter catch plus material collected ahead of the filter in the sampling train. The amount of filter catch is determined by the difference in the weight of the filter before and after the test, after dessicating. The particulate matter from other portions of the train was determined by rinsing the probe, cyclone and all glassware ahead of the filter with acetone, evaporating to dryness and weighing.

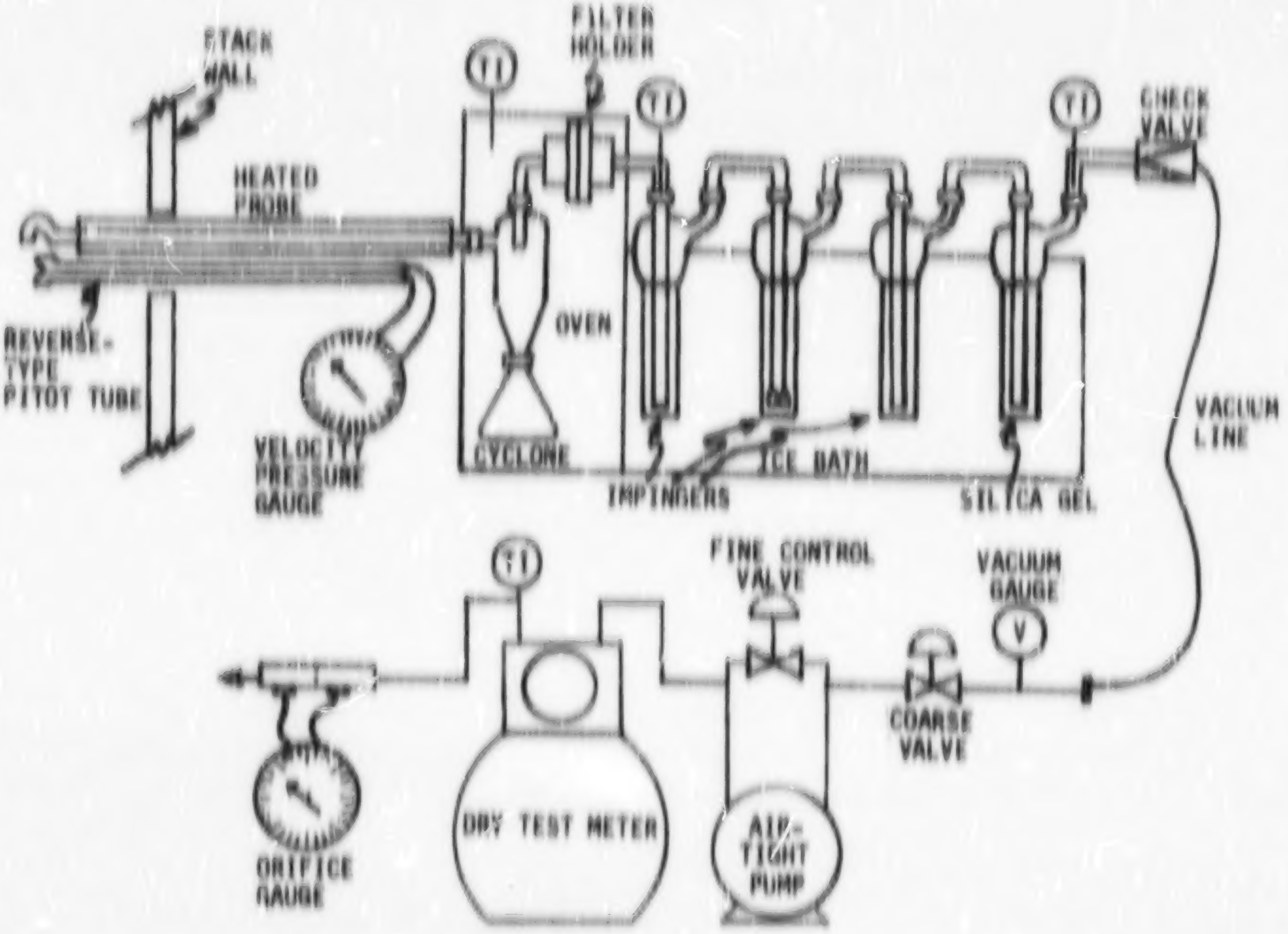
STACK WALL
HEATED PROBE
REVERSE-TYPE PITOT TUBE
VELOCITY PRESSURE GAUGE
TI
FILTER HOLDER
TI
TI
CHECK VALVE
CYCLONE
OVEN
IMPINGERS
ICE BATH
SILICA GEL
VACUUM LINE
TI
FINE CONTROL VALVE
VACUUM GAUGE
V
COARSE VALVE
ORIFICE GAUGE
DRY TEST METER
AIR-TIGHT PUMP

FIGURE 7

PARTICULATE SAMPLING TRAIN

6.2 NITROGEN OXIDE

Using method 7, gas samples were withdrawn from the stack into evacuated 2-liter flasks containing a dilute solution of hydrogen peroxide and sulfuric acid. The hydrogen peroxide oxidizes the lower oxides of nitrogen (except nitrous oxide) to nitric acid. The resultant solution is evaporated to dryness and treated with phenol disulfonic acid reagent and ammonium hydroxide. The yellow trialkali salt of 6-nitro-1-phenol-2, 4-disulfonic acid is formed, which is measured colorimetrically.

6.3 SULFURIC ACID MIST AND SULFUR DIOXIDE

The Shell method was chosen for this determination due to uncertainties which exist about the validity of the results using method 8.* A gas sample is drawn from the stack using a heated probe and passed through a water-cooled coil condenser maintained below the dew point of sulfuric acid at 140°-194°F, followed by a fritted glass plate and then passed through a chilled impinger train with two impingers containing an isopropanol and hydrogen peroxide mixture and followed by an impinger containing silica gel for drying. This setup is shown in Figure 8.

The condensed sulfuric acid mist in the coil condenser is water washed from the condenser. The final determination is made by titrating the solution with barium chloride, using a thorin indicator. Isopropanol must be added to the solution to be titrated to improve the rapidity with which the barium sulfate precipitates during titration.

---

* Lisle, E.S. and J.D. Sensenbaugh, "The Determination of Sulfur Trioxide and Acid Dew Point in Flue Gases," Combustion, Jan. 1965.

Goksoyr, H. and K. Ross, "The Determination of Sulfur Trioxide in Flue Gases," J. Inst. Fuel, No. 35, 177, (1962)

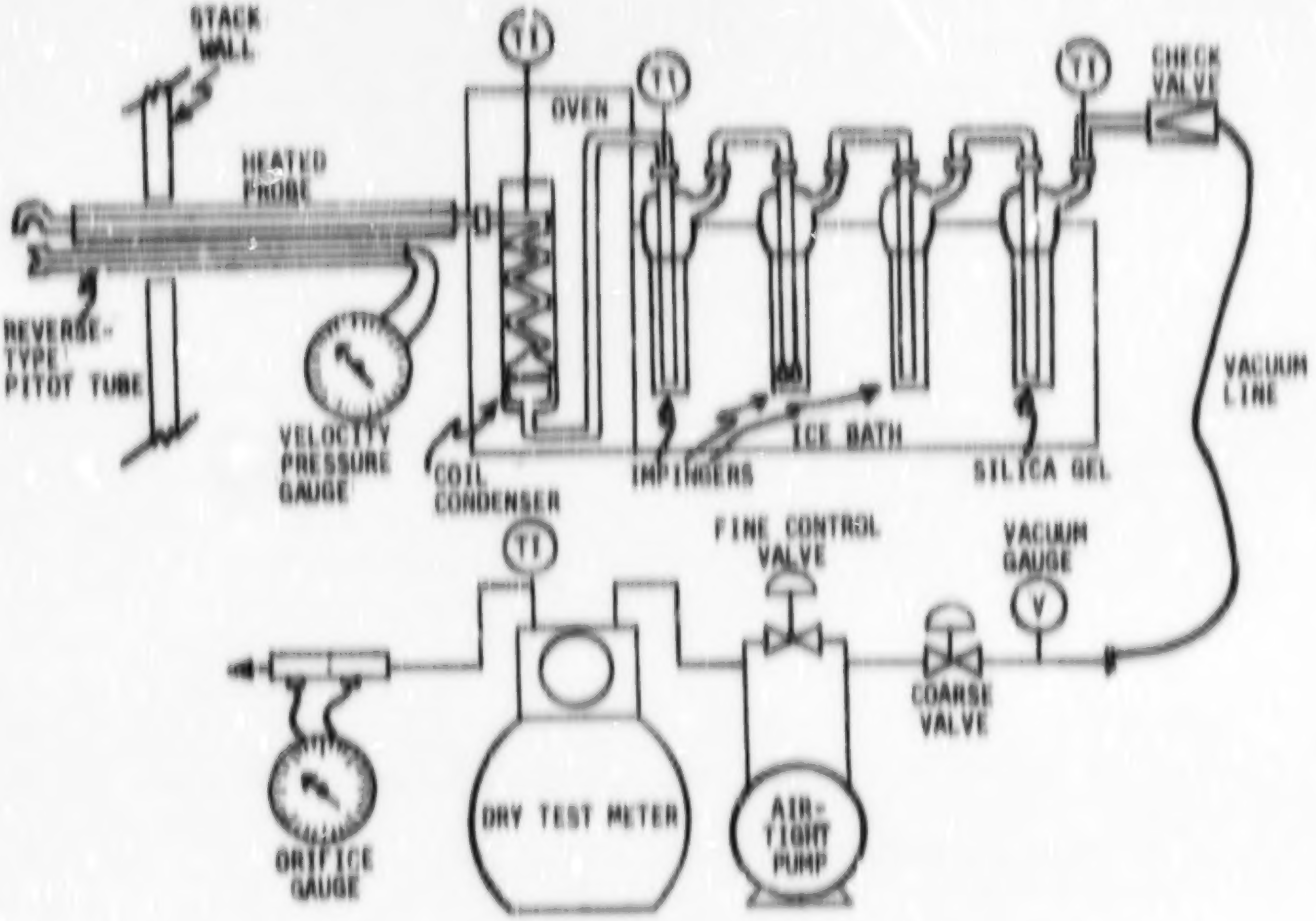
STACK WALL
HEATED PROBE
REVERSE-TYPE PITOT TUBE
VELOCITY PRESSURE GAUGE
TT
OVEN
COIL CONDENSER
IMPINGERS
ICE BATH
SILICA GEL
CHECK VALVE
VACUUM LINE
FINE CONTROL VALVE
VACUUM GAUGE
V
COARSE VALVE
AIR-TIGHT PUMP
DRY TEST METER
ORIFICE GAUGE

FIGURE 8

SULFURIC ACID MIST SAMPLING TRAIN

Sulfur dioxide in the gas sample is oxidized to sulfur trioxide in the impingers containing the hydrogen peroxide. Sulfur dioxide is then determined by titrating the hydrogen peroxide solution with barium chloride, using a thorin indicator.

6.4 PARTICLE SIZE

An Anderson fractioning inertial impactor is used for the determination of particle size in the range of approximately 0.5 to 12.0 microns. The sampling head is placed in the oven after the heated sampling probe and a sample of stack gas is drawn isokinetically through the sampler. The particulate matter is fractionated and collected on the plates inside the sample head and a determination is made by the difference in weight of the plates before and after testing. Results are expressed for particles of [illegible] nsity. The sampling head assembly is shown in Figure 9.

6.5 HYDROCARBONS

Gas samples were withdrawn from the stack using a vacuum pump to fill Tedlar bags. The composition of the hydrocarbons was determined by gas chromatograph utilizing a Beck[illegible] 6800 for CO, CH_4, and total hydrocarbons and a Perkin Elmer 900 for the complete hydrocarbon breakdown.

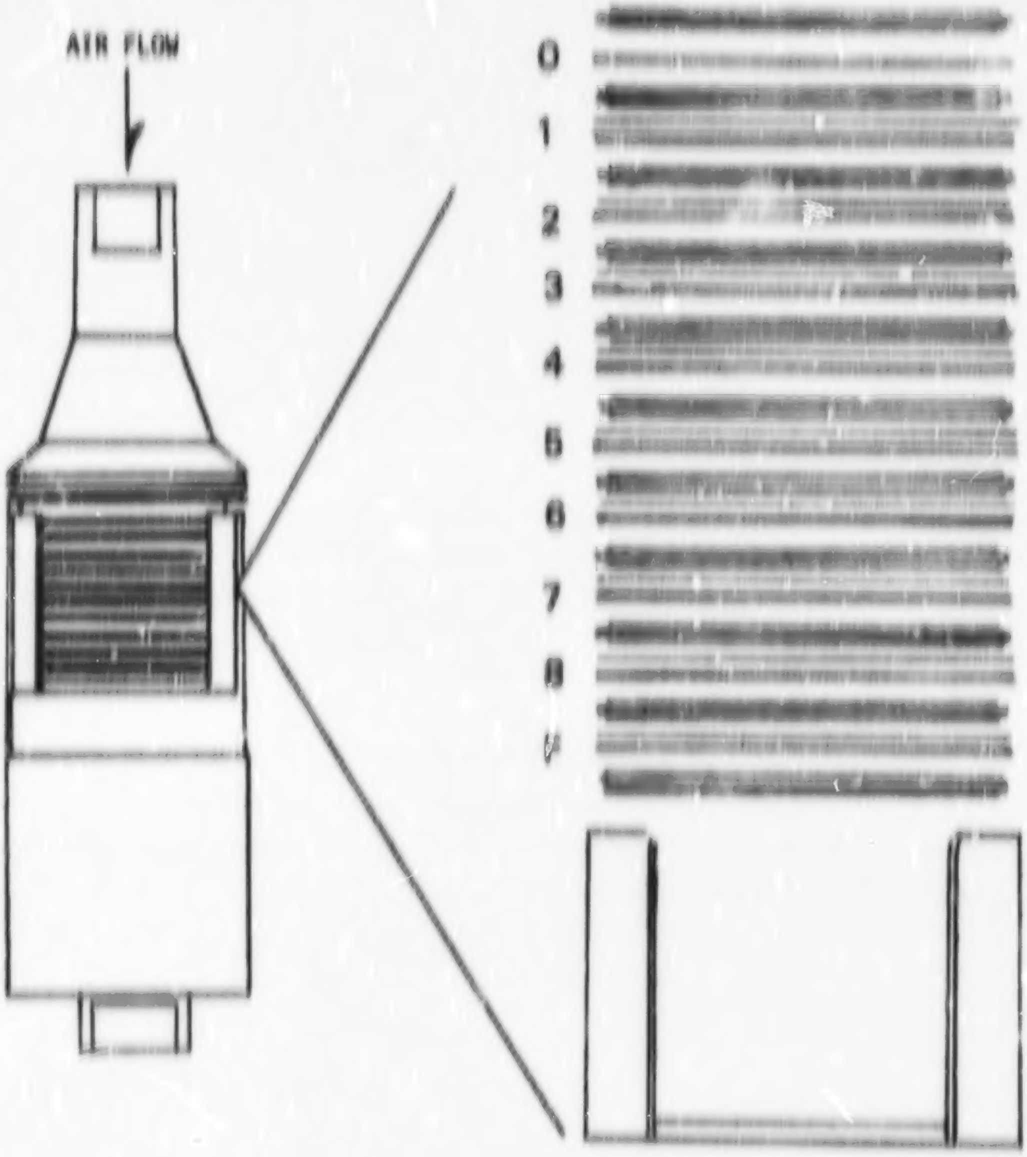
AIR FLOW
0
1
2
3
4
5
6
7
8

FIGURE 9
ANDERSEN STACK SAMPLER

7.0 RESULTS

Results obtained from the test on boiler no. 6 are shown in Table 1. Results obtained from the test on the Catalytic Cracker Regenerator are shown in Table 2. Although these tests were performed for research purposes, standard EPA methods were used. Since the test on the Catalytic Cracker Regenerator may be used for compliance, it is of interest to compare the results with the State of Illinois standards. A comparison is shown in Table 3.

In addition to measuring particulate loadings on boiler no. 6, a particle size analysis was made using an Andersen impactor. The results are shown in Table 4 and Figure 10.

The average results of hydrocarbon samples taken on boiler no. 6 on 4 and 5 November are:

Carbon Monoxide:	1.11 ppm
Methane:	1.07 ppm
Total Hydrocarbons, as CH_4	3.28 ppm

The major hydrocarbon components of these samples are given in Table 5.

The average results of hydrocarbon samples taken on the Catalytic Cracker Regenerator on 10 and 12 November are:

Carbon Monoxide:	28.91 ppm
Methane:	0.13 ppm

Total hydrocarbon results are not available due to a malfunction of the analyzer. A complete analysis of the major components indicates that the total hydrocarbons are approximately 2-3 ppm. The major components are given in Table 6.

TABLE 1

SUMMARY OF RESULTS - BOILER NO. 6

Date	11/4	11/5	11/6		
Stack Flow Rate - SCFM * dry	54,013	47,766	42,348		
% Water Vapor - % Vol.	13.19	12.67			
% CO_2 - Vol % dry	10.33	10.83			
% O_2 - Vol % dry	5.90	6.30			
% Excess air @ sampling point	35.6	39.6			
SO_2 Emissions - lbs/10^6 Btu			1.83		
NO_x Emissions - lbs/10^6 Btu	0.45	0.58			
H_2SO_4 Mist - lbs/10^6 Btu			0.021		
Particulates Probe, Cyclone, & Filter Catch lbs./hr.					
lbs/10^6 Btu					
Total Catch					
lbs./hr.	26.4	32.2			
lbs/10^6 Btu	0.14	0.18			
% Isokinetic Sampling	100.4	92.7			

*70° F, 29.92" Hg

TABLE 2

SUMMARY OF RESULTS - CATALYTIC CRACKER REGENERATOR

Date	11/12	11/17			
Stack Flow Rate - SCFM * dry	87,367	84,642			
% Water Vapor - % Vol.	27.98	29.9			
% CO_2 - Vol % dry	16.5	17.2			
% O_2 - Vol % dry	1.65	1.4			
% Excess air @ sampling point	8.1	6.8			
SO_2 Emissions - PPM		419			
NO_x Emissions - PPM	71.2	362.7			
H_2SO_4 Mist - PPM		3.4			
Particulates Probe, Cyclone, & Filter Catch					
lbs./hr.					
lbs/10^6 Btu					
Total Catch					
lbs./hr.	18.7	27.4			
lbs/10^6 Btu					
% Isokinetic Sampling	110.3	100.26			

*70° F, 29.92" Hg

TABLE 3

COMPARISON OF RESULTS

SOURCE	POLLUTANT	ILLINOIS STATE STANDARD	AMOUNT FOUND
Boiler No. 6	Particulates	0.1 lb/10^6 Btu	0.16 lb/10^6 Btu
	SO_2	1 lb/10^6 Btu	1.9 lb/10^6 Btu
	CO	200 ppm	1.1 ppm
Catalytic Cracker Regenerator	Particulates	80.1 lb/hr	23.1 lb/hr
	SO_2	2000 ppm	419.0 ppm
	CO	200 ppm	28.6 ppm

TABLE 4

PARTICLE SIZE DETERMINATION

TEST: AMOCO - BOILER NO. 6 DATE: 11/5

Plate	Filter Net (mg)	% Of Total	ECD (microns)
1	0.0	0.0	14.4 & above
2	0.0	0.0	9.1
3	4.0	3.57	6.1
4	4.7	4.19	4.3
5	6.9	6.16	2.6
6	9.8	8.74	1.4
7	11.7	10.44	0.84
8	15.1	13.47	0.56
Backup	59.9	53.43	<0.56
	112.1	100.00	

TEST: AMOCO - BOILER NO. 6 DATE: 11/6

Plate	Filter Net (mg)	% Of Total	ECD (microns)
1	1.7	2.75	14.2 & above
2	4.6	7.44	9.0
3	1.4	2.27	6.0
4	2.6	4.21	4.3
5	2.7	4.37	2.6
6	5.1	8.25	1.4
7	6.1	9.87	0.83
8	8.9	14.40	0.55
Backup	28.7	46.44	<0.55
	61.8	100.00	

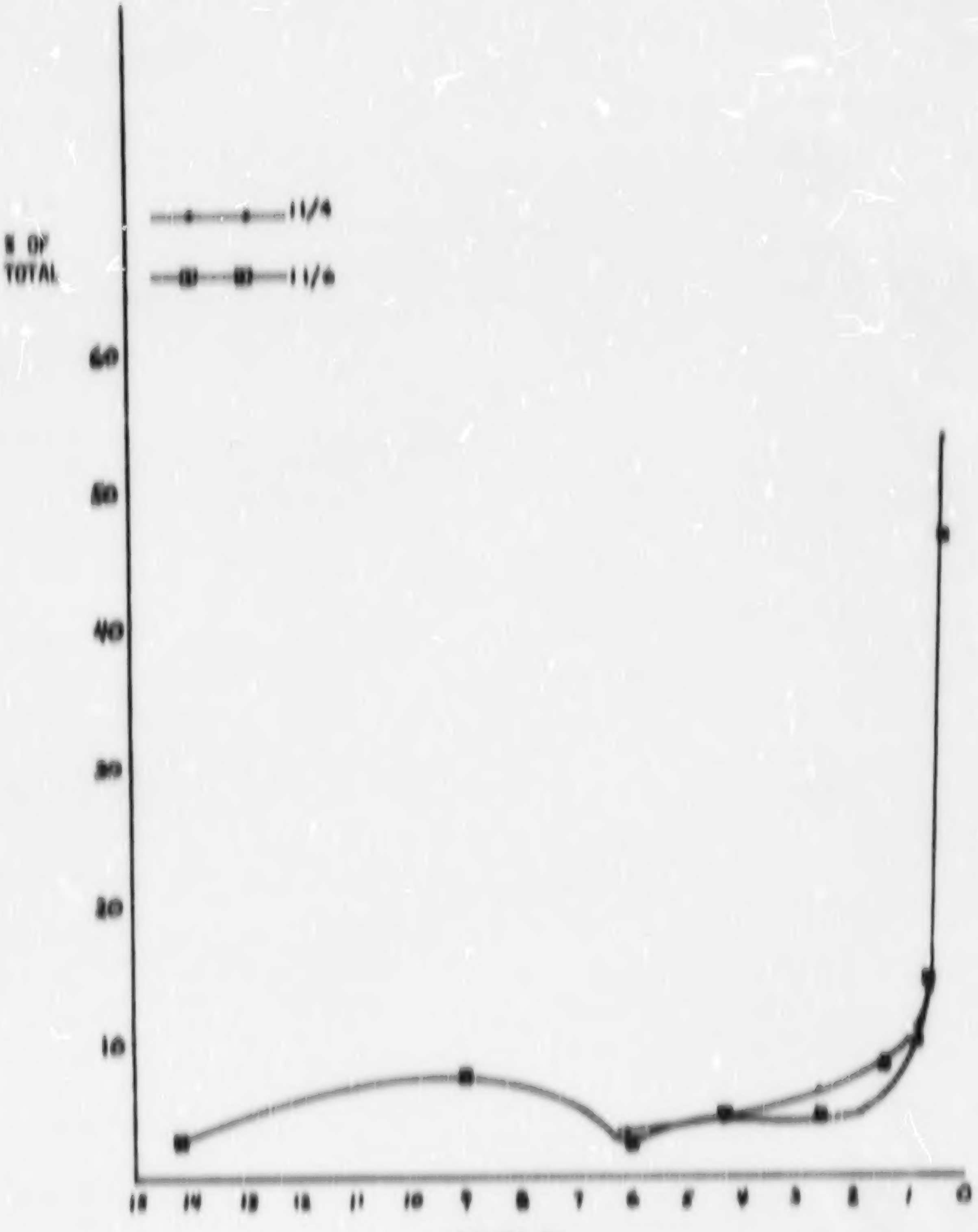

FIGURE 10

PARTICLE SIZE DISTRIBUTION-BOILER NO. 6

TABLE 5
HYDROCARBON ANALYSIS
BOILER NO. 6

COMPOUND	CONCENTRATION (ppb as C)	
	11/4	11/5
Ethane	20.7	16.8
Ethylene	36.3	27.8
n-Propane	36.5	34.3
Acetylene	35.0	32.8
n-Butane	55.7	52.2
Isopentane	11.1	7.6
n-Pentane	5.4	8.4
Hexane	23.7	33.0
Benzene + 2,4 DM-C_5		18.5
Heptane		15.1
2,5 dimethyl Hexane		10.9
Toluene	33.3	94.6
1, Octene	38.9	128.5
Octane	4.1	9.1
Ethyl Benzene	24.3	56.7
m, p-Xylene	123.2	290.3
o-Xylene	37.5	70.0
Nonane	13.2	19.1
n-Propyl Benzene	9.7	49.6
1,3,5 trimethyl Benzene	16.4	

TABLE 6

HYDROCARBON ANALYSIS
CAT CRACKER REGENERATOR

COMPOUND	CONCENTRATION (ppb as C) 11/10	 11/12
Ethane		19.5
Ethylene		12.8
n-Propane		51.3
Acetylene		9.5
Isobutane		16.7
n-Butane		4.7
Propylene		3.7
Isopentane		1.4
n-Pentane		5.1
Hexane	41.3	
Benzene + 2,4 DM Pentane	38.1	
Heptane	27.6	
Toluene	46.1	
1, Octene	29.3	
Octane	4.4	
Ethyl Benzene	18.6	
m,p-Xylene	111.2	
o-Xylene	38.1	
Nonane	10.4	

APPENDIX A
PARTICULATE CALCULATIONS

PARTICULATE CALCULATIONS

Volume of dry gas sampled at standard conditions - 70° F, 29.92 "Hg

$$Vm_{std} = \left(\frac{Vm}{Cf_m}\right)\left(\frac{Pm}{Pstd}\right)\left(\frac{Tstd}{Tm}\right) = 0.0334\left(\frac{Vm}{1.021}\right)\left(P_B + \frac{\Delta H}{13.6}\right)$$

Vm_{std} = Volume of dry gas sampled at standard conditions, ft^3

Vm = Meter volume sampled, ft^3

1.021 = Meter correction factor

P_m = Meter pressure, barometric pressure, P_B, plus orifice pressure, ΔH, in. Hg.

Pstd = Standard pressure, 29.92 in. Hg.

Tstd = Standard temperature, 530° R or 70° F

Tm = Meter temperature, 530° R for compensated meter

Cfm = Meter correction factor

Volume of water vapor at standard conditions

$$Vw = V_{l_c}\left(\frac{\rho H_2O}{MH_2O}\right)\left(\frac{R\ Tstd}{Pstd}\right) \quad \frac{lb.}{454\ gm.} = 0.0474 \times V_{l_c}$$

Vw = Volume of water vapor at standard conditions, ft^3

V_{l_c} = Volume of liquid collected in impingers and silica gel, ml.

ρH_2O = Density of water, 1g/ml.

M H_2O = Molecular weight of water, 18 lb/lb mol

R = Ideal gas constant, 21.83 in. Hg. - cu. ft./lb-mol - °R

% Moisture in Stack Gas

$$\%\ M = 100 \times \frac{Vw\ std}{Vm_{std} + Vw_{std}}$$

Average molecular weight of dry stack gas

$$MW_D = \left(\%CO_2 \times \frac{44}{100} \right) + \left(\% \, O_2 \times \frac{32}{100} \right) + \left(\% \, N_2 \times \frac{28}{100} \right)$$

Molecular weight of stack gas

$$MW_W = \left(\frac{100 - \% \, M}{100} \times MW_D \right) + \left(\frac{\%M}{100} \times 18 \right)$$

Stack velocity at stack conditions

$$V_s = 85.48 \times C_p \left(\frac{Ts \times \Delta P \text{ avg.}}{Ps \times MW_W} \right)^{1/2}$$

V_s = stack velocity, fps.

85.48 = pitot constant, $\frac{\text{ft.}}{\text{sec.}} \left(\frac{\text{lb.}}{\text{lb. Mole - oR}} \right)^{1/2}$

C_p = pitot coefficient, dimensionless

T_s = average stack temperature, °R

P_s = stack pressure, barometric pressure plus static pressure, in. Hg.

ΔP Avg = average differential pressure, in. H_2O

Stack gas volume at standard conditions

$$Qs = 3600 \left(1 - \frac{\%M}{100} \right) V_s \; A \left(\frac{Tstd}{Ts} \; \frac{Ps}{Pstd} \right)$$

Q_s = stack gas volume flow rate, SCF/hr

A = stack cross sectional area, ft^2

3600 = seconds per hour

$Qs' = Q_s \div 60$ = SCFM

Per cent isokinetic sampling

$$I = \frac{1.667\left[(0.00267)\quad V_{lc} \quad + \quad \frac{V_{mc}}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right] T_s}{\theta\ V_s\ P_s\ A_n}$$

I = per cent isokinetic sampling

1.667 = minutes per second, X 100

$0.00267 = \frac{\rho_{H_2O}}{M_{H_2O}} \times R \times \frac{lb.}{454\ gm.}$

θ = sampling time, min.

A_n = cross sectional area of sampling nozzle, ft^2

Particulate emission

$C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{Vm_{std}}\right)$

C_s = particulate emission, lb/scf

2.205×10^{-6} = pounds per mg.

Mn = total mass of particulate collected, mg.

$C_E = C_s \times Q_s$ = lb/hr

C_E = particulate emission per hour

$C_H = C_E \div H$

C_H = particulate emission, lb. per million BTU

H = heat input, million BTU per hour

Excess air at sample point

$$\% \text{ EA} = \frac{100 \times \% \text{ O}_2}{(0.266 \times \% \text{ N}_2) - \% \text{ O}_2}$$

% EA = excess air at sample point, %

0.266 = ratio of oxygen to nitrogen in air by volume

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Blr 6 - Run 1 **Date:** 11/4/78

Material collected (mg) =

Filter Catch = 217.3
Dry Catch =
Acetone Wash = 59.7

TOTAL = 277.0

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_b + \frac{H}{13.6}\right)$

$0.0334 \frac{(76.078)}{(1.01)}\left(29.68 + \frac{0.9675}{13.6}\right) = \underline{74.850}$ SCF

Volume of water vapor Vw = 0.0474 X Vlc

0.0474 (240 ml) = 11.376 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(11.376)}{(74.85) + (11.376)} = \underline{13.19}$ %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(10.53 \times 0.44) + (5.9 \times 0.32) + (83.77 \times 0.28) = \underline{29.881}$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 13.19}{100} \times 29.881\right] + \left[\frac{13.19}{100} \times 18\right] = \underline{28.121}$

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 6 - Run 1 **Date:** 11/4/86

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times \Delta P\ avg}{P_s \times Mw_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{896.5 \times 0.154}{29.64 \times 28.321}\right]^{1/2} =$ 30.10 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{B_w}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(13.19)}{100}\right](30.1)\ (86.749)\ \frac{530}{(896)}\ \frac{(29.08)}{29.92} =$ 3,246,613 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6} \left\{\frac{277}{74.85}\right\} =$ 8.16×10^{-6} lb/scf

$C_E = C_s \times Q_s = (8.16 \times 10^{-6})\ \ (3,246613) =$ 26.44 lb/hr

$C_H = C_E \div H = \left\{\frac{26.44}{188.8}\right\} =$ 0.14 lb/10⁶ Btu

Isokinetic Variations $I = \frac{1.667\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right]T_s}{\theta\ V_s\ P_s\ A_n}$

$\frac{1.667\left[(0.00267)\ \ (240) + \frac{75.325}{530}\left(29.68 + \frac{0.9698}{13.6}\right)\right](896.88)}{(108)\ \ (30.10)\ \ (29.08)\ \ (3.67 \times 10^{-4})} = 100.37$

Excess Air at Sample Point

$\% EA = \frac{100 \times \% O_2}{(0.266 \times \% N_2) - \% O_2}$

$\frac{100\ (5.9)}{(0.266 \times 81.17) - (5.9)} =$ 35.0

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Blr. 6 - Run 2 **Date:** 11/5/75

Material collected (mg) =

Filter Catch = 290.9
Dry Catch =
Acetone Wash = 89.7

TOTAL = 380.6

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \frac{(69.718)}{(1.01)}\left(29.75 + \frac{0.8196}{13.6}\right) = \underline{68.748}$ SCF

Volume of water vapor Vw = 0.0474 X Vlc

0.0474 (210.4 ml) = 9.973 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(9.973)}{(68.748) + (9.973)} = \underline{12.67}$ %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(10.85 \times 0.44) + (6.5 \times 0.32) + (82.65 \times 0.28) = \underline{29.973}$

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 12.67}{100} \times 29.973\right] + \left[\frac{12.67}{100} \times 18\right] = \underline{28.456}$

PARTICULATE SAMPLING CALCULATIONS

Test: Blr. 6 - Run 2 Date: 11/5/75

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times \Delta P\ avg}{P_s \times Mw_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{908.42 \times 0.1324}{29.71 \times 28.156}\right]^{1/2} =$ 27.73 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%H}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(12.67)}{100}\right](27.73)\ (56.748)\ \frac{530}{(908)}\ \frac{(29.71)}{29.92} =$ 2,866,983 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(350.6)}{(68.748)} =$ 1.125×10^{-5} lb/scf

$C_E = C_s \times Q_s = (1.125 \times 10^{-5})\ (2,865,783) =$ 32.229 lb/hr

$C_H = C_E \div H = \frac{(32.229)}{(177.0)} =$ 0.18 lb/10⁶ Btu

Isokinetic Variations $I = 1.667\ \frac{\left[(0.00267)\ V_{1_c} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right] T_s}{\theta\ V_s\ P_s\ A_n}$

$1.667\ \frac{\left[(0.00267)\ (210.4) + \frac{75.325}{530}\left(29.75 + \frac{0.876}{13.6}\right)\right](908.42)}{(124)\ (27.73)\ (29.71)\ (7.67 \times 10^{-4})} = 92.7\%$

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (6.3)}{(0.266 \times 82.40) - (6.3)} = 40\%$

NO$_x$ EMISSION DATA

Boiler No. 6

Date 11/4/75

Run No.	1	2	3	4	5	6	7	8
Time	1045	1055	1130	1236	1250	1510	1515	1600
µg NO$_2$	548	674	76	422	394	1000	1105	1045
T$_i$ - Initial Flask Temp. °R	525	525	515	525	525	515	515	515
T$_f$ - Final Flask Temp. °R	545	545	545	545	545	545	545	545
V$_{fc}$ - Flask Volume, ml.	2047	2038	2039	2028	2025	2052	2054	2056
P$_i$ - Initial Flask Pres. "Hg	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
P$_f$ - Final Flask Pres. "Hg	29.68	29.68	29.68	29.68	29.68	29.68	29.68	29.68
lb/scf NO$_2$ x10^{-5}	1.89	2.35	0.26	1.47	1.37	3.44	3.80	3.58
lb/10^{6}Btu NO$_2$	0.33	0.41	0.05	0.26	0.24	0.60	0.67	0.63

$$V_{sc} = \left(17.71 \frac{°R}{\text{in. Hg}}\right) (V_{fc}) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = \text{scf}$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{\text{lb/scf}}{\mu\text{g/ml}} \left(\frac{\mu\text{g NO}_2}{V_{sc}}\right) = \text{lb/scf NO}_2$$

NO_x EMISSION DATA

Boiler No. 6 Date 11/8/78

Run No.	1	2	3	4	5	6		
Time	0930	1000	1030	1400	1400	1405		
µg NO_2	965	1110	910	950	1085	1160		
T_i - Initial Flask Temp, °F	530	530	530	530	530	530		
T_f - Final Flask Temp, °F	550	550	550	550	550	550		
V_{fc} - Flask Volume, ml.	2047	2038	2059	2018	2085	2082		
P_i - Initial Flask Pres, "Hg	2.5	2.5	1.5	2.5	2.5	2.5		
P_f - Final Flask Pres, "Hg	29.75	29.75	29.75	29.75	29.75	29.75		
lb/scf NO_2 $\times 10^{-5}$	3.14	3.56	3.16	3.22	3.60	4.01		
lb/10^6Btu NO_2	0.54	0.62	0.51	0.54	0.61	0.68		

$$Vsc = \left(17.71 \frac{°R}{in.\ Hg}\right) (Vfc) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = scf$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \frac{lb/scf}{\mu g/ml} \left(\frac{\mu g\ NO_2}{Vsc}\right) = lb/scf\ NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Boiler No. 4

Date	11/6		11/6			
Run No.	1	1	2	2		
V_{mc}-Meter Volume, Ft^3	6.057		7.858			
Vmstd-Meter Volume, Std. Cond.	5.988		7.768			
P_B-Barometric Pressure, "Hg	29.59		29.59			
ΔH-Avg. Orifice Pres. Drop, "H_2O	0.1		0.1			
V_t-Vol. of Titrant, ml.	9.8	1.6	15.05	3.05		
V_{tb}-Vol. of Titrant for Blank, ml.	nil		nil			
Vsoln-Vol. of Solution, ml.	500	100	500	100		
V_a-Vol. of Aliquot, Titrated, ml.	5	25	5	25		
lb/scf H_2SO_4 $\times 10^{-6}$		1.154		1.696		
lb/10^6 Btu H_2SO_4		0.017		0.025		
lb-scf SO_2 $\times 10^{-4}$	1.154		1.366			
lb/10^6 Btu SO_2	1.77		2.04			

$$Vmstd = 0.0334 \frac{(Vm)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$CH_2SO_4 = \frac{\left(1.08 \times 10^{-4} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) \quad (\underline{N}) \quad \left(\frac{V_{soln}}{Va}\right)}{V_{mstd}} = lb/scf$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$CSO_2 = \frac{\left(7.05 \times 10^{-5} \frac{lb\text{-}l}{g\text{-}ml}\right) (V_t - V_{tb}) \quad (\underline{N}) \quad \left(\frac{V_{soln}}{Va}\right)}{V_{mstd}} = lb/scf$$

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Cat Cracker **Date:** 11/18/75

Material collected (mg) =

Filter Catch	= 33.0
Dry Catch	=
Acetone Wash	= 32.9
TOTAL	= 65.9

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{Cf_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \frac{(42.90)}{(1.01)}\left(29.48 + \frac{0.926}{13.6}\right) =$ 41.736 SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

0.0474 (342 ml) = 16.211 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(15.911)}{(41.736) + (16.211)} =$ 27.976 %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(16.5 \times 0.44) + (1.65 \times 0.32) + (81.85 \times 0.28) =$ 30.706

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 27.976}{100} \times 30.706\right] + \left[\frac{27.976}{100} \times 18\right] =$ 27.151

PARTICULATE SAMPLING CALCULATIONS

Test: Cat Cracker **Date:** 11/18/78

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times P\ avg}{P_s \times Mw_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{1012.1 \times 0.914}{29.361 \times 27.181}\right]^{1/2} =$ 78.269 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%H}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(27.976)}{100}\right](78.269)\ (80.265)\ \frac{530}{(1012)}\ \frac{(29.360)}{29.92} =$ 5,241,998 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \frac{(65.9)}{(41.736)} =$ 3.482×10^{-6} lb/scf

$C_E = C_s \times Q_s = (3.482 \times 10^{-6})\ (5,241,998) =$ 18.25 lb/hr

$C_H = C_F \div H = \{\_\_\_\_\_\} =$ ________ lb/10⁶ Btu

Isokinetic Variations $I = 1.667 \frac{\left[(0.00267)\ V_{lc} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right] T_s}{\theta\ V_s\ P_s\ A_n}$

$1.667 \frac{\left[(0.00267)\ (342) + \frac{41.736}{530}\left(29.42 + \frac{0.986}{13.6}\right)\right](1012.1)}{(60)\ (78.269)\ (29.361)\ (3.4 \times 10^{-4})} =$ 106.338

Excess Air at Sample Point

$\%\ EA = \frac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\frac{100\ (1.65)}{(0.266\ (81.86)) - (1.65)} =$ 8.2 %

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Cat Cracker **Date:** 11/17/78

Material collected (mg) =

Filter Catch	=	32.9
Dry Catch	=	
Acetone Wash	=	51.8
TOTAL	=	84.7

Gas Volume $Vm_{std} = 0.0334 \left(\frac{V_m}{CF_m}\right)\left(P_B + \frac{H}{13.6}\right)$

$0.0334 \frac{(35.31)}{(1.01)} \left(29.68 + \frac{0.653}{13.6}\right) =$ 34.614 SCF

Volume of water vapor $Vw = 0.0474 \times Vlc$

0.0474 (311.6 ml) = 14.768 SCF

% Moisture $\%M = 100 \times \frac{Vwstd}{Vmstd + Vwstd}$

$100 \times \frac{(14.768)}{(34.614) + (14.768)} =$ 29.9 %

Molecular Weight of dry stack gas

$MW_D = \%CO2 \times 0.44 + \%O2 \times 0.32 + \%N2 \times 0.28$

$(17.7 \times 0.44) + (1.4 \times 0.32) + (81.4 \times 0.28) =$ 31.028

Molecular Weight of stack gas

$MWw = \frac{100 - \%M}{100} \times MW_D + \frac{\%M}{100} \times 18$

$\left[\frac{100 - 29.9}{100} \times 31.028\right] + \left[\frac{29.9}{100} \times 18\right] =$ 27.13

PARTICULATE SAMPLING CALCULATIONS

Test: Amoco - Cat Cracker **Date:** 11/17/78

Stack Velocity $V_s = 85.48 \times C_p \left[\frac{T_s \times P\ avg}{P_s \times Mw_w}\right]^{1/2}$

$85.48 \times (0.86) \left[\frac{1039.3 \times 0.900}{29.614 \times 27.13}\right]^{1/2} =$ 79.32 fps

Stack Gas Volume $Q_s = 3600\left(1 - \frac{\%M}{100}\right)(V_s)(A)\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)$

$3600 \left[1 - \frac{(29.9)}{100}\right](79.32)\ (50.160)\ \frac{530}{(1039)}\ \frac{(29.614)}{29.92} =$ 5,018,548 SCFH

Stack Emission Rate $C_s = 2.205 \times 10^{-6}\left(\frac{M_n}{V_{Mstd}}\right)$

$2.205 \times 10^{-6}\ \left(\frac{84.7}{34.614}\right) =$ 5.3956 ×10⁻⁶ lb/scf

$C_E = C_s \times Q_s = (5.396 \times 10^{-6})\ (5,018,548) =$ 27.40 lb/hr

$C_H = C_E \div H = \{\quad\} =$ ______ lb/10⁶ Btu

Isokinetic Variations $I = \dfrac{1.667\left[(0.00267)\ V_{1c} + \frac{V_m}{T_m}\left(P_B + \frac{\Delta H}{13.6}\right)\right]T_s}{\theta\ V_s\ P_s\ A_n}$

$\dfrac{1.667\left[(0.00267)\ (311.5) + \frac{34.614}{530}\left(29.68 + \frac{0.684}{13.6}\right)\right](1039.3)}{(60)\ (79.32)\ (29.614)\ (8.4 \times 10^{-4})} =$ 100.26%

Excess Air at Sample Point

$\%\ EA = \dfrac{100 \times \%\ O_2}{(0.266 \times \%\ N_2) - \%\ O_2}$

$\dfrac{100\ (1.4)}{(0.266 \times 81.4) - (1.4)} =$ 6.9 %

APPENDIX B
FIELD DATA

NO_x EMISSION DATA

Cat. Cracker

Date 11/12 & 11/17

	11/12		11/17					
Run No.	1	2	3	4	5	6	7	8
Time	1015	1115	1210	1135	1305	1500	1520	1540
$\mu g\ NO_2$	242	246	1000	1700	1180	1900	1580	1620
T_i - Initial Flask Temp, °R	510	510	510	530	530	530	530	530
T_f - Final Flask Temp, °R	530	530	550	550	550	550	550	550
V_{fc} - Flask Volume, ml.	2047	2032	2039	2028	2022	2052	2024	2026
P_i - Initial Flask Pres, "Hg	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
P_f - Final Flask Pres, "Hg	29.42	29.44	29.61	29.61	29.61	29.61	29.61	29.61
lb/scf NO_2 $\times 10^{-6}$	0.93	0.84	3.80	4.32	4.15	4.26	4.22	4.43
$lb/10^6$ Btu NO_2								
lb/hr NO_x	42.6	43.5	180.6	215.8	214.2	235.8	236.3	275.3

$$V_{sc} = \left(17.71 \frac{°R}{in.\ Hg}\right) (V_{fc}) \left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right) = scf$$

$$V_{fc} = V_f - 25$$

$$C = 6.2 \times 10^{-5} \ \frac{lb/scf}{\mu g/ml} \left(\frac{\mu g\ NO_2}{V_{sc}}\right) = lb/scf\ NO_2$$

H_2SO_4 MIST and SO_2 EMISSION DATA

Cat Cracker

Date		11/17		11/17			
Run No.		1		2			
V_{mc}-Meter Volume,	Ft^3	7.386		11.955			
Vmstd-Meter Volume, Std. Cond.		7.1065		11.886			
P_B-Barometric Pressure, "Hg		29.61		29.61			
ΔH-Avg. Orifice Pres. Drop, "H_2O		0.1		0.1			
V_t-Vol. of Titrant, ml.		7.1	0.3		8.75		
V_{tb}-Vol. of Titrant for Blank, ml.		nil	nil	nil	nil		
Vsoln-Vol. of Solution, ml.		500	100		100		
V_a-Vol. of Aliquot, Titrated, ml.		5	50		50		
lb/scf H_2SO_4	$x10^{-6}$		0.089		1.518		
lb/10^6 Btu H_2SO_4	lb/hr		0.46		8.25		
lb-scf SO_2	$x10^{-5}$	6.881		6.856			
lb/10^6 Btu SO_2	lb/hr	383.8		383.8			

$$\text{Vmstd} = 0.0334 \frac{(V_m)}{CF_m} \left(P_B + \frac{\Delta H}{13.6}\right)$$

CF_m = Meter correction factor

$$C_{H_2SO_4} = \frac{\left(1.08 \times 10^{-4} \frac{\text{lb-l}}{\text{g-ml}}\right) (V_t - V_{tb}) \ (\underline{N}) \left(\frac{V_{soln}}{V_a}\right)}{V_{mstd}} = \text{lb/scf}$$

$\underline{N}$ = 0.01 Normal Barium Perchlorate

$$C_{SO_2} = \frac{\left(7.05 \times 10^{-5} \frac{\text{lb-l}}{\text{g-ml}}\right) (V_t - V_{tb}) \ (\underline{N}) \left(\frac{V_{soln}}{V_a}\right)}{V_{mstd}} = \text{lb/scf}$$

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Boiler No. 6

Date	11/4	11/5	11/6	
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr	see	below		
Boiler Heat Input				
Fuel Burning Rate - lb/hr				
Fuel Heating Value - BTU/lb				
Fuel Sulfur Content - %				
Fuel Ash Content - %				
Fuel Moisture Content %				

Steam loads checked over time of test

11/4

Part. 155.3×10^3 lb/hr = 185.8×10^6 Btu/hr

NO_x 154.2×10^3 lb/hr = 184.5×10^6 Btu/hr

Andersen 150.4×10^3 lb/hr = 180.0×10^6 Btu/hr

11/5

Part. 147.9×10^3 lb/hr = 177.0×10^6 Btu/hr

NO_x 148.4×10^3 lb/hr = 177.6×10^6 Btu/hr

Andersen 150.6×10^3 lb/hr = 180.2×10^6 Btu/hr

11/6

Andersen 140.6×10^3 lb/hr = 168.3×10^6 Btu/hr

$SO_2 + SO_3$ 142.1×10^3 lb/hr = 170.1×10^6 Btu/hr

Boiler Feedwater : 290°F, 800 psi H = 259.3 Btu/lb

Steam : 600 psig, superheated, 680°F H = 1276.5 Btu/lb

Heat Output = 1276.5 − 259.3 = 1017.2 Btu / lb steam

Heat Input = Output ÷ 85% = 1017.2 ÷ 0.85

= 1196.7 Btu / lb steam

ORSAT FIELD DATA

Location Amoco - Blr #6 Comments:

Date 11/4 - 11/6

Time

Operator Klein

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
11/4 1015	10.6	5.7	0.0
1030	10.4	5.8	0.0
1600	10.0	6.2	0.0
11/5 1340	11.0	6.4	0.0
1430	10.7	6.5	0.0
0910	10.8	6.0	0.0
11/6	9.2	7.0	0.0

Plant Amoco
Run No. 1
Location #6 Blr.
Date 11/4/75
Operator Grissom, Klein
Meter ΔH@ 1.026
C Factor

PARTICULATE FIELD DATA
VERY IMPORTANT–FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 65
Bar. Press "Hg 29.68
Assumed Moisture % 10
Probe Tip Dia., In. 3/8
Probe Length 10'-5"
Avg. ΔP ______ Avg. ΔH ______

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. ~~Hg~~ H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	10:40	1886.415	0.08	0.52	0.52	190	64		310	150	-0.6	200
1-2	:43	1888.1	0.11	0.70	0.70	226	57	5.0	310	200		380
1-3	:46	1890.6	0.12	0.75	0.75	230	55		318	230		430
1-4	:49	1891.8	0.14	0.9	0.9	245	57		325	245		445
1-5	:52	1894.2	0.16	1.0	1.0	250	59	7.5	330	245		440
1-6	:55	1895.9	0.16	1.0	1.0	255	60		330	250		450
1-7	:58	1898.3	0.16	1.0	1.0	265	60		335	245		450
1-8	11:01	1900.3	0.16	1.0	1.0	270	66		335	230		445
1-9	:04	1902.8	0.16	1.0	1.0	275	68		340	235		455
1-10	:07	1905	0.165	1.05	1.05	280	65	8.0	350	240		455
1-11	:10	1907	0.16	1.0	1.0	280	63		350			
1-12	:13	1909.2	0.16	1.0	1.0	285	60		345	305		450
1-13	:16	1911.5	0.16	1.0	1.0	285	60		345			450
1-14	:19	1913.5	0.18	1.15	1.15	290	60		345	255		460
1-15	:22	1916	0.18	1.15	1.15	290	61	9.0	345	255		450
1-16	:25	1918.3	0.18	1.15	1.15	295	62		345	260		460
1-17	:28	1920.8	0.19	1.2	1.2	295	62		345	300		455
1-18	:31	1923	0.19	1.2	1.2	295	63		345	300		455

Zero readings on approx. all points with pitot @ 90°
[illegible] = 1922.00 V_s = 38.585

Point	Clock	Dry Gas Meter, CF	Pitot in H₂O ΔP	Orifice ΔH in H₂O		Impinger °F Temp.		Pump Vacuum in. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg	Stack Temp °F
				Desired	Actual	Inlet	Outlet					
2-9	12 27	[illegible]	[illegible]	0.75	0.75	175	61	6.0	300	[illegible]		440
-10	30	[illegible]	0.52	0.95	0.95	200	54	7.2	300	270		453
-11	:33	1420.5	0.17	1.05	1.05				[illegible]	270		455
-12	:36	[illegible]	0.15	1.16	1.16	255	56	15	[illegible]	[illegible]		455
-13	:39	[illegible]	[illegible]	1.16	1.16	230	56		[illegible]	234		455
-14	:42	[illegible]	0.2	1.25	1.25	255	57		[illegible]	225		[illegible]
-15	:45	[illegible]	0.2	1.25	1.25	260	57	9.5	320	230		455
-16	:48	[illegible]	0.22	1.4	1.4	260	57		330	225		460
-17	:51	[illegible]	0.20	1.25	1.25	270	55		[illegible]	225		460
-18	:54	[illegible]	0.18	1.15	1.15	270	55		323	215		455
OFF	12 57	[illegible]										
3-1	1 25	[illegible]	[illegible]	0.5	0.5	175	61		270	320		260
-2	:31	[illegible]	[illegible]	0.63	0.63	230	58	6.0	315	330		[illegible]
-3	:34	1451.0	[illegible]	0.7	0.7	270	57	6.2	330	[illegible]		453
-4	:37	[illegible]	[illegible]	0.75	0.75	246	57	6.7	315	325		455
-5	:40	[illegible]	0.12	0.75	0.75	260	[illegible]		350	325		460
-6	:43	[illegible]	0.12	0.75	0.7	265	60	7.0	325	325		460
-7	:46	[illegible]	0.13	0.72	0.72	265	60		325	335		463
-8	:49	[illegible]	0.14	0.9	0.9	270	62		328	335		466
OFF	:52	[illegible]										
			[illegible]		[illegible]							[illegible]
	54											[illegible]

COMMENTS: [illegible]

[illegible]

PARTICULATE CLEANUP SHEET

Date: 11/4/86

Plant: [illegible]

Run Number: 1

Location Of Sample Port: #6 Lig Stack

Operator:

Barometric Pressure: 29.61

Sample Box No.

Ambient Temperature 65°

Impinger H2O

Volume After Sampling 375 ml

Impinger Prefilled With 200 ml

Volume Collected 175 ml

Silica Gel

Weight After 545 g

Weight Before 500 g

Moisture Weight 45 g Moisture Total 220 g

Dry Probe and Cyclone Catch:

Container No.

Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No.

Extra No. Weight Results [illegible] g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
13			

11/4

Filter Particulate Weight 0.2173 g

Total Particulate Weight 0.4772 g

% Moisture By Volume

PARTICULATE FIELD DATA

VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Plant Amoco

Run No. 2

Location #6 Blr.

Date 11/5/75

Operator Grisson, Klein

Meter ΔH@ 1.026

C Factor

Ambient Temp °F 70

Bar. Press "Hg 29.75

Assumed Moisture % 12

Probe Tip Dia., In. 3/8

Probe Length 5 ft & 10 ft

Avg. ΔP 0.17 Avg. ΔH

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-1	9:35	2003.455	0.08	0.5	0.5	120	70	4.5	300	260	-0.55	310
2-2	9:38	2005.0	0.1	0.625	0.625	160	57		305	280		425
2-3	:41	2007.1	0.095	0.57	0.59	195	58	6.0	310	290		450
2-4	:44	2008.7	0.11	0.68	0.68	210	59	5.5	325	310		460
2-5	:47	2010.6	0.11	0.68	0.68	220	60		330	300		460
2-6	:50	2012.7	0.12	0.75	0.75	232	64		340	315		460
2-7	:53	2014.0	0.12	0.75	0.75	240	66		340	323		462
2-8	:56	2016.1	0.12	0.75	0.75	240	68		333	320		465
off	9:59	2017.990										
2-9	10:15	2017.990	0.13	0.8	0.8	160	71		310	180		465
2-10	:18	2019.7	0.13	0.8	0.8	228	65	6.0	313	180		462
2-11	:21	2021.7	0.13	0.8	0.8	245	62		312	200		460
2-12	:24	2023.7	0.14	0.86	0.86							465
2-13	:27	2025.7	0.14	0.86	0.86	250	65	7.0	325	205		472
2-14	:30	2027.6	0.16	1.0	1.0	255	62		323	200		470
2-15	:33	2029.7	0.16	1.0	1.0			3.5				470
2-16	:36	2031.7	0.16	1.0	1.0							470
2-17	:39	2034.1	0.15	0.93	0.93							480
2-18	:42	2036.0	0.14	0.86	0.86	250	64	3.0	315	200		450
end	10:45	2038.150										

Short Probe

↑

↓

Long Probe

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-1	11:38	2038.015	0.08	0.5	0.5	150	70	4.5	280	190		365
1-2	:41	2039.6	0.10	0.62	0.62	200	66		280	205		415
1-3	:44	2041.4	0.12	0.74	0.75	210	65		286	235		445
1-4	:47	2043.3	0.12	0.74	0.74							450
1-5	:50	2045.0	0.15	0.93	0.93	225	69	7.5	315	230		455
1-6	:53	2047.3	0.14	0.86	0.86							460
1-7	:56	2049.0	0.14	0.86	0.86							460
1-8	:59	2051.2	0.14	0.86	0.86							460
1-9	12:02	2053.4	0.13	0.8	0.8	230	69		325	225		455
1-10	:05	2055.2	0.13	0.8	0.8							460
1-11	:08	2056.6	0.14	0.86	0.86							460
1-12	:11	2058.9	0.14	0.86	0.86			7.0				460
1-13	:14	2061.2	0.15	0.93	0.93							460
1-14	:17	2063.0	0.15	0.93	0.93							460
1-15	:20	2064.9	0.15	0.93	0.93							460
1-16	:23	2067.1	0.16	1.0	1.0							460
1-17	:26	2069.1	0.16	1.0	1.0							460
1-18	:29	2071.2	0.17	1.05	1.05							460
off	12:32	2073.220										
Total	54 min	35.205	0.1324		0.856							448.4

COMMENTS:

PARTICULATE CLEANUP SHEET

Date: 11/8/85 Plant:

Run Number: 3 Location Of Sample Port: #6 Blr

Operator: Barometric Pressure:

Sample Box No. Ambient Temperature

Impinger H2O

Volume After Sampling 373 ml

Impinger Prefilled With 200 ml

Volume Collected 173 ml

Silica Gel

Weight After 577.4 g

Weight Before 540.0 g

Moisture Weight 37.4 g Moisture Total 210.4 g

Dry Probe and Cyclone Catch:

Container No.

Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No.

Extra No. Weight Results .0177 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.

Filter Particulate
Weight 0.3999 g

Total Particulate
Weight 0.4176 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 11/9/[illegible]

Plant [illegible] Power Plant

Sample Collected By Klein

Field Data

Clock Time	10:45	10:58	11:30	12:30	12:[illegible]	[illegible]	[illegible]	[illegible]
Flask number	1	2	3	4	5	6	7	[illegible]
Volume of flask (ml)*	2047	2038	2037	2025	2035	[illegible]	[illegible]	[illegible]
Pressure before sampling in. Hg.	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Pressure after sampling, in. Hg.	29.69	"	"	"	"	"	"	"
Flask temperature, °F	75	"	"	"	"	"	"	"

* Flask + valve - 25 ml. for absorbing solution

OXIDES OF NITROGEN FIELD DATA

Date 11/8/75

Plant Amoco - Bh #6

Sample Collected By Klein

Field Data

Clock Time	0930	1000	1030	1200	1400	1405		
Flask number	1	2	3	4	5	6		
Volume of flask (ml)*	2047	2038	2039	2028	2015	2052		
Pressure before sampling in. Hg.	2.5	2.5	2.5	2.5	2.5	2.5		
Pressure after sampling, in. Hg.	29.75	29.75	29.75	29.75	29.75	29.75		
Flask temperature, °F	90	90	90	90	90	90		

* Flask + valve - 25 ml. for absorbing solution

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 11/6/75

Plant Asarco   Location #6 Boiler

Bar. Pressure 29.59 "Hg   Comments:

Ambient Temp 75 °F

Run No 1

Power Stat Setting ______

Filter Used: Yes ______ No ____

Operator Grissom, Klein

Clock Time	Meter (Ft.³)	Pitot in. H2O ΔP	Orifice in H2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger	
							In	Out
10:40	2125.895	0.1	0.1	425	320	122	140	79
10:45	2127.3	0.1	0.1	425	305	142	180	76
10:50	2128.7	0.1	0.1	425	315	144	160	75
10:55	2130.1	0.11	0.1	435	320	145	145	75
11:00	2131.4	0.1	0.1	440	325	146	140	75
11:05	2132.013							

Comments: 6.118 ft³
25.4 min

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 11/6/75

Plant Allied

Location #6 Boiler

Bar. Pressure 29.59 "Hg

Comments:

Ambient Temp 42° °F

Run No 2

Power Stat Setting

Filter Used: Yes No

Operator Gelston, Klein

Clock Time	Meter (Ft.^{3})	Pitot in. H_2O ΔP	Orifice in H_2O ΔH	Temperatures °F				
				Stack	Probe	Coil	Impinger	
							In	Out
11:30	2132.013	0.1	0.1	425	295	152	175	75
11:40	2134.65	0.1	0.1	440	320	157	160	80
11:45	2136.0	0.1	0.1	445	306	158	145	80
11:50	2137.8	0.1	0.1	440	300	157	140	75
11:55	2138.7	0.1	0.1	440	300	157	135	80
12:10	2139.970							

Comments: 7.957 ft^3

Plant	Amoco
Run No.	Anderson #1
Location	#6 Blr
Date	1-14-75
Operator	Grissom, Klein
Meter ΔH	
C Factor	

PARTICULATE FIELD DATA

VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Filter Set No. 1

Backup No. 1

Ambient Temp °F	70
Bar. Press "Hg	29.62
Assumed Moisture %	10
Probe Tip Dia., In.	3/8
Probe Length	5 ft
Avg. ΔP	
Avg. ΔH	

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-4	3:03	1962.495	0.12	0.85	0.85	285	75	7.0	360	340		460
	:13	1964.1	0.12		0.85	280	70	10.0	365	370		460
	:23	1976.0	0.13		0.85	300	70	11.0	390	360		460
	:33	1981.25	0.13		0.85	295	75	14.0	385	365		460
	:43	1988.10	0.12		0.85	300	80	16.5	360	360		460
off	:53	1995.615	0.14		0.8			18.5				

50.25 min 32.12 ft³

[illegible]

Plant: [illegible]
Run No.: [illegible]
Location: [illegible]
Date: [illegible]
Operator: [illegible]
Meter Box No.:
C Factor:

PARTICULATE FIELD DATA
VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

[illegible]

Ambient Temp °F: 80
Bar. Press "Hg: [illegible]
Assumed Moisture %: [illegible]
Probe Tip Dia., In:
Probe Length:
[illegible]

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Dry Gas Temp. °F		Pump Vacuum In. Hg Gauge	Box Temp °F	Probe Temp °F	Stack Press. in. Hg	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
[illegible]	[illegible]	[illegible]	[illegible]	1.8	1.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		480
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		480
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	325	[illegible]		480
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		345	[illegible]		480
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		340	[illegible]		480
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		480
	[illegible]	[illegible]										

Plant: Amoco
Run No. Autoclave #3
Location #4 Blr.
Date 11/6/75
Operator Garrison Klein
Meter ΔH@ 1.022
C Factor 0.495

PARTICULATE FIELD DATA
VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 72
Bar. Press "Hg 28.64
Assumed Moisture % 12
Probe Tip Dia., In. 3/8
Probe Length 5 ft
Avg. ΔP ______ Avg. ΔH ______

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. Hg.	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-8	9:15	2106.475	0.14	0.75	0.75	220	75	4.0	350	340		490
	:20	2109.7	0.11		0.75	265	62	9.2	340	340		465
	:25	2113.0	0.11		0.75	275	66	10.0	365	330		435
	:30	2116.3	0.12	0.75	0.75	295	69	10.1	380	345		415
	:35	2119.5	0.14	0.75	0.75	310	70	10.4	385	340		490
	:40	2124.6	0.14	0.75	0.75	315	72	10.7	388	345		495
	9:45	2125.085										

19.405 ÷ 30 = 0.649 cfm

358.2

Particle Size Determination

Test: Amoco - Blr. 6 Date: 11/4/78
Oven Temp. = 380°F

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1817	0.1817		0.0		0.0	0.0	14.4 & above
2	0.1448	0.1448		0.0		0.0	0.0	9.12
3	0.1570	0.1610		4.0		3.57	3.57	6.12
4	0.1596	0.1643		4.7		4.19	7.76	4.32
5	0.1550	0.1619		6.9		6.16	13.92	2.64
6	0.1488	0.1586		9.8		8.74	22.66	1.368
7	0.1530	0.1647		11.7		10.44	33.10	0.84
8	0.1500	0.1651		15.1		13.47	46.57	0.56
Back Up Filter	0.2140	0.2739		59.9		53.43	100.0	<0.56
		Total		112.1		100.0		

Test: Amoco - Blr. 6 Date: 11/5/78
Oven Temp. = 375.4°F

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1603	0.1609		0.6		0.54		14.4 & above
2	0.1470	0.1481		1.1		0.99		9.0
3	0.1462	0.1506		4.4		3.97		6.0
4	0.1498	0.1561		6.3		5.69		4.20
5	0.1444	0.1502		5.8		5.24		2.88
6	0.1489	0.1619		13.0		11.75		1.36
7	0.1464	0.1593		12.9		11.65		0.88
8	0.1426	0.1593		16.7		15.09		0.58
Back Up Filter	Forgot filter assume = avg first & third runs			49.9		45.08		<0.58
		Total		110.7		100.00		

Particle Size Determination

Test: Amoco - Blr. 6 Date: 11/6/78
Oven Temp. = 272.2 °F

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1	0.1521	0.1538		1.7		2.75		14.23 & above
2	0.1411	0.1457		4.6		7.44		8.97
3	0.1429	0.1443		1.4		2.27		5.78
4	0.1452	0.1478		2.6		4.21		4.25
5	0.1461	0.1488		2.7		4.37		2.63
6	0.1426	0.1477		5.1		8.25		1.35
7	0.1431	0.1492		6.1		9.87		0.83
8	0.1461	0.1550		8.9		14.40		0.55
Back Up Filter	0.2121	0.2408		28.7		46.44		<0.55
		Total		61.8		100.00		

Test: Date:

Plate	Tare(g)	Final(g)	Net(mg)	Filter Net	Total	% of Total	Cum %	ECD (Microns)
1								
2								
3								
4								
5								
6								
7								
8								
Back Up Filter								
		Total						

SUPPLEMENTARY PROCESS DATA FOR POWER PLANTS

Date				
Net Unit Load - MW				
Average Steam Load - 10^3 lb/hr				
Boiler Heat Input				
Fuel Burning Rate - lb/hr				
Fuel Heating Value - BTU/lb				
Fuel Sulfur Content - %				
Fuel Ash Content - %				
Fuel Moisture Content %				

Operating Data for Cat Cracker

Date	Fresh Feed (Bbl/day)	Total Feed (Bbl/day)	HCCO Recycle Rate (Bbl/day)	Slurry Rate (Bbl/day)	Catalyst Circulation Rate (tons/min)
11/18	34486	35811	489	835	20.6
11/17	34769	35991	485	716	19.8

HCCO → Heavy Cat Cycle Oil

ORSAT FIELD DATA

Location Amoco Cat Cracker Comments:

Date 11/12 & 11/17

Time

Operator

Test	(CO_2) Reading 1	(O_2) Reading 2	(CO) Reading 3
11/12 1000	16.4	2.0	0.0
1100	16.6	1.3	0.0
11/17 1130	16.8	2.2	0.0
1320	17.2	1.4	0.0

Plant Amoco
Run No. 1
Location Cat Cracker
Date 11/12
Operator Grissom, Klein
Meter ΔH@ 1.022
C Factor 0.40

PARTICULATE FIELD DATA
VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Ambient Temp °F 50
Bar. Press "Hg 29.42
Assumed Moisture % 20
Probe Tip Dia., In. 1/4
Probe Length 10 ft
Avg. ΔP 0.8 Avg. ΔH

Point	Clock	Dry Gas Meter, CF	Pitot in H_2O ΔP	Orifice ΔH in H_2O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. H_2O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
1-6	10:30	2142.930	0.90	0.92	0.92	120	95	10.0	225		-0.8	550
1-5	:35	2147	0.85	0.86	0.86	175	44	9.5	235	200		560
1-4	:40	2150	0.75	0.76	0.76	195	45	8.5	260	170		565
1-3	:45	2152.7	0.85	0.86	0.86	210	45	9.5	290			560
1-2	:50	2157	0.95	0.96	0.96	230	45	10.5	305			560
1-1	:55	2161	0.85	0.86	0.86	240	48	10.0	320			540
off	11:00	2163.860										
2-6	12:00	2163.860	0.82	0.85	0.85	160	50	9.5	320	180		545
2-5	:05	2167.2	0.80	0.82	0.82	270	48		325	240		550
2-4	:10	2171	0.9	0.92	0.92	270	55	10.5	330			555
2-3	:15	2174.8	1.1	1.1	1.1	285	64	12.5	325			550
2-2	:20	2178.5	1.1	1.1	1.1	290	68		335			550
2-1	:25	2182.5	1.1	1.1	1.1	300	72		340			540
off	12:30	2185.730										

V_m = 42.80   0.94   0.96   552.1

PARTICULATE CLEANUP SHEET

Date: 11/8/85

Plant: Astoria

Run Number: #1

Location Of Sample Port: [illegible]

Operator:

Barometric Pressure: 29.42

Sample Box No.

Ambient Temperature 80°F

Impinger H2O

Volume After Sampling 531 ml

Impinger Prefilled With 200 ml

Volume Collected 331 ml

Silica Gel

Weight After 631 g

Weight Before 415 g

Moisture Weight 216 g Moisture Total 547 g

Dry Probe and Cyclone Catch:

Container No.

Extra No. Weight Results g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No.

Extra No. Weight Results 0.0128 g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
14			

Filter Particulate Weight [illegible] g

Total Particulate Weight 0.0607 g

% Moisture By Volume

Plant Amoco
Run No. 2
Location Cat Cracker
Date 11/17
Operator Grissom, Klein
Meter ΔH 1.822
C Factor 0.3

PARTICULATE FIELD DATA
VERY IMPORTANT-FILL IN ALL BLANKS

Read and record at the start of each test point.

Filter #16

Ambient Temp °F 65
Bar. Press "Hg 29.68
Assumed Moisture % 30
Probe Tip Dia., In. 1/4
Probe Length 10 ft
Avg. ΔP ______ Avg. ΔH ______

Point	Clock	Dry Gas Meter, CF	Pitot in H₂O ΔP	Orifice ΔH in H₂O		Impinger °F Temp.		Pump Vacuum In. Hg. Gauge	Box Temp °F	Probe Temp °F	Stack Press. In. H₂O	Stack Temp. °F
				Desired	Actual	Inlet	Outlet					
2-6	1035	2185.890	0.9	0.66	0.66	165	65	7.0	265		-0.9	580
2-5	1040	2189	0.85	0.61	0.61	210	53	6.5	295	260		585
2-4	1045	2192	0.75	0.54	0.54	240	55	6.0	320	250		590
2-3	:50	2194.5	0.95	0.68	0.68	255	58		340			585
2-2	:55	2197.5	1.0	0.72	0.72	265	59		350			585
2-1	1100	2201	0.95	0.68	0.68	270	60	7.0	350			560
off	1105	2201.680										
1-6	1240	2202.480	0.95	0.68	0.68	170	70	7.0	264			580
1-5	:45	2206.5	0.90	0.66	0.66	230	60	7.0	303	250		583
1-4	:50		0.75	0.54	0.54	252	64		316	275		583
1-3	:55	2210.5	0.9	0.66	0.66	260	68	7.6	322			580
1-2	1300	2215	1.0	0.72	0.72	275	66		340			580
1-1	:05	2218	0.9	0.66	0.66	280	63	7.0	345			580
off	1310	2221.620										

V_m = 36.31   0.900   0.652   579.3

PARTICULATE CLEANUP SHEET

Date: 11/12/76 Plant: [illegible]

Run Number: 2 Location Of Sample Port: [illegible]

Operator: ____ Barometric Pressure: 29.6

Sample Box No. ____ Ambient Temperature 68 °F

Impinger H2O

Volume After Sampling 520 ml

Impinger Prefilled With 200 ml

Volume Collected 320 ml

Silica Gel

Weight After 533.5 g

Weight Before 500 g

Moisture Weight 33.5 g Moisture Total 353.5 g

Dry Probe and Cyclone Catch:

Container No. ____

Extra No. ____ Weight Results 0.0818 g

Probe, Cyclone, Flask
And Front Of Filter
Acetone Wash:

Container No. ____

Extra No. ____ Weight Results ____ g

Filter Papers and Dry Filter Particulate

Filter No.	Container No.	Filter No.	Container No.
15			

Filter Particulate Weight 0.0339 g

Total Particulate Weight 0.1157 g

% Moisture By Volume

OXIDES OF NITROGEN FIELD DATA

Date 11/18 & 11/19

Plant Amoco - Cat Cracker

Sample Collected By Klein

Field Data

	11/18		11/19					
Clock Time	1015	1115	1110	1215	1305	1500	1530	1540
Flask number	1	2	3	4	5	6	7	8
Volume of flask (ml)*	2047	2038	2019	2028	2018	2052	2052	2056
Pressure before sampling in. Hg.	1.5	———	———	———	———	———	———	———
Pressure after sampling, in. Hg.	29.41	29.41	29.61	29.61	29.61	29.61	29.61	29.61
Flask temperature, °F	70	70	90	90	90	90	90	90

* Flask + valve - 25 ml. for absorbing solution

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 11/17/85

Plant Amax

Location Central Precipitator

Bar. Pressure 29.61 "Hg

Comments: Precipitator not in operation

Ambient Temp 70 °F

Run No 1

Power Stat Setting

Filter Used: Yes ____ No ____

Operator Gerlach, Klein

Clock Time	Meter (Ft.³)	Pitot in. H2O ΔP	Orifice in H2O ΔH	Temperatures °F Stack	Probe	Coil	Impinger In	Out
2:25	2221.010	0.8	0.1	585	220	168	150	70
2:30	2222.3	0.8	0.1	585	210	170	190	67
2:35	2223.6	0.8	0.1	585	200	170	160	66
2:40	2224.9	0.75	0.1	590	205	170	155	66
2:45								
2:50	2227.3	0.8	0.1	590	215	177	190	66
off 2:55	2228.470							

Comments: 7.46 ft³

GAS SAMPLING FIELD DATA

Material Sampled For SO_2 & SO_3

Date 11/19/76

Plant [illegible]

Location [illegible] Precipitator

Bar. Pressure ________ "Hg

Comments: [illegible]

Ambient Temp 70 °F

Run No 2

Power Stat Setting ________

Filter Used: Yes ________ No ____

Operator [illegible]

Clock Time	Meter (Ft.³)	Pitot in. H2O ΔP	Orifice in H2O ΔH	Temperatures °F Stack	Probe	Coil	Impinger In	Out
[illegible]	2221.575	0.8	0.1	590	205	170	140	[illegible]
[illegible]	[illegible]	0.75	0.1	595	210	178	160	[illegible]
[illegible]	[illegible]	0.8	0.1	600	205		145	60
[illegible]	[illegible]	0.8	0.1	600	215	160	145	[illegible]
[illegible]	[illegible]							

Comments: [illegible]